Technical Report 960

The Effects of Procedural Structure and Computer Support Upon Selecting a Tactical Course of Action

Jon J. Fallesen
U.S. Army Research Institute

Charles F. Carter, Jr., and Mike S. Perkins
Science Applications International Corp.

Rex R. Michel
U.S. Army Research Institute

James P. Flanagan and Paul E. McKeown
Science Applications International Corp.

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EDGAR M. JOHNSON
Technical Director

MICHAEL D. SHALER
COL, AR
Commanding

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Technical review by

Kathleen A. Quinkert
Douglas K. Spiegel

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Fallesen, Jon J. (ARI); Carter, Jr., Charles E.; Perkins, Mike S. (SAIC); Michel, Rex R. (ARI); Flanagan, James P.; McKeown, Paul E. (SAIC)

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The U.S. Army wants its commanders and their staffs to consider a broad range of factors and to make tactical decisions quickly. The Estimate of the Situation is a standard process for teaching tactical decision making. An experiment was conducted to compare structured procedures for the Estimate to a condition where procedures were unspecified and to computer-supported procedures. The structured procedures were enforced through refresher training, written instructions, and manual job aids. In the unspecified condition, teams were explicitly instructed only to select a course of action (COA) and to justify their selection. Computer support was provided in the third condition by providing a prototype tactical data system with a spreadsheet tool for war gaming the COAs.

The structured and computer-supported treatments led to significantly better justifications for COA selection than did the unspecified condition. Even though computer-supported teams had only about 2 hours of instruction, there was no difference in the quality of structured and computer-supported solutions. Most of the structured teams made arithmetic errors when comparing COAs; the (Continued)

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computer-supported teams did not. Based on the results, future enhancements should be targeted at visualizing and understanding battle events and projecting battle outcomes.

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Science Applications International Corp.

Rex R. Michel
U.S. Army Research Institute

James P. Flanagan and Paul E. McKeown
Science Applications International Corp.

Field Unit at Fort Leavenworth, Kansas
Stanley M. Halpin, Chief

Manpower and Personnel Research Division
Zita M. Simutis, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
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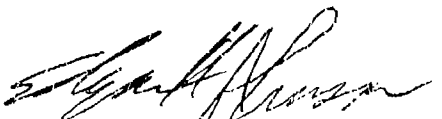
Human Factors in Training and
Operational Effectiveness

Command and control (C^2) and tactical decision making are growing in importance for both the wartime Army and for peacetime training. Decisions and the commands that put them into effect mold a tactical force into shape for a combat operation. Decisions made about execution and the control that is accomplished maintain and refine the form and substance of that force. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Leavenworth Field Unit continues to examine tactical decision making. This study looks at tactical decision making in the context of planning a battlefield operation.

The Estimate of the Situation is the military's process to support decision making. One major subtask of the Estimate involves course of action (COA) analysis, selection, and justification. This research examines staff officer performance when the task is structured through manual job aids and computer information management tools. These conditions are compared to a case where procedures go unspecified and the participants are free to use their own approaches for COA selection.

The research was performed under the ARI research task entitled "Enhancing Command Staff Performance in Combat Operations." The work was performed in accordance with the Memorandum of Agreement with the Combined Arms Combat Development Activity entitled, "Development and Implementation of the Future Battle Laboratory," dated 30 June 1989. Initial results were presented to the Combined Arms Command's Command and Control Integration Council and at the 28th Army Operations Research Symposium during the fall of 1989. As findings from this research became available, they were transitioned as C^2 lessons learned for Operation Desert Shield ("Winning in the Desert II: Tactics, Techniques, and Procedures for Maneuver Commanders," Center for Army Lessons Learned Special Edition Newsletter No. 90-8, Sep 90) and revisions to FM 101-5 ("Command and Control for Commanders and Staffs," Coordinating Draft, Jun 90).



EDGAR M. JOHNSON
Technical Director

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The talents of many people from Science Applications International Corp. created the Tactical Planning Workstation and Course of Action Assessment Tool. Principal designers and software developers were Bruce Packard, Laura McClanahan, C. Glenn Ross, Richard Zarse, and Doug Williams.

Finally, the thorough efforts of reviewers Douglas Spiegel and Kathleen Quinkert are recognized. They diligently waded through earlier, lengthy drafts and are largely responsible for improvements. Any remaining errors, ambiguities, or unclear sections remain the responsibility of the authors.

THE EFFECTS OF PROCEDURAL STRUCTURE AND COMPUTER SUPPORT UPON SELECTING A TACTICAL COURSE OF ACTION

EXECUTIVE SUMMARY

Requirement:

It is generally thought that there are three ways to improve decision making: selection of good decision makers, training good decision makers, and aiding the process of decision making. An essential ingredient for all three is an understanding of human decision-making requirements. The U.S. Army is interested in decisions about tactical courses of action. The Estimate of the Situation is the doctrinal process for making tactical decisions.

Informal observation of the procedures used for making tactical decisions in field, laboratory, and classroom settings led to the researchers' conclusion that there is a discrepancy between how the Estimate is described in training and field manuals and how it is actually performed. Key Army individuals have acknowledged that Estimate materials are designed for an officer with little or no experience in higher echelon, tactical decision making and with unlimited time to follow the process. In wartime conflicts and in field training exercises, there is little time to complete an entire Estimate. Unfortunately, there are not standard Estimate materials for these more important cases.

The goal of this research was to better understand tactical decision making by looking more closely at one phase of the Estimate--selecting and justifying a course of action. The three primary objectives were to find out

- the extent to which Estimate procedures are followed,
- if better decisions result when procedures are used, and
- if decisions are improved when they are aided by computers.

Procedure:

An experiment was used to examine the objectives. Two participants similar in rank to those on division operations and plans staffs and with Command and General Staff Officer College education were teamed together to perform the task. The team was to select and justify a course of action (COA) in a division-level offensive operation. Each of 14 teams was assigned to one of three experimental conditions. One condition used unspecified procedures. The unspecified condition presented the team with the goal

of selecting and justifying a COA. Scenario information was available in notebooks and on maps in doctrinally prescribed formats for information, such as higher command's warning order, situation overlays, previous estimates, unit status reports, and reference information. The second condition separated the task into nine steps, requiring a team to follow step instructions and to complete work sheets associated with each step. The same scenario information was available to the teams in this structured condition. The third condition was similar to the structured case, but instead of retrieving information from the scenario notebooks, a tactical computer information system was used. Also, instead of completing work sheets as in the structured condition, the computer-supported teams had various computer word processing, map, and spreadsheet tools available for some of the steps.

The experiment used several data collection methods to address a broad range of topics, including task performance (identification of facts, force arrays, critical events, war gaming COAs, comparing COAs, and justifying selection of a COA), task duration times, early decisions, workload, situational awareness, performance process (work management, team dynamics, knowledge, style), task assessment, cognitive abilities, computer experience, relative importance of data, human-machine interface design, and task-aiding possibilities. An expert panel solution was developed over a period of months before data collection and was used in scoring and comparing participant team results for task performance measures.

Findings:

Structured and computer-supported teams ranked significantly higher than the unspecified teams on the quality of their COA justification. Unspecified teams did not perform the task in the same way as teams required to follow the procedural Estimate guidance. Unspecified teams left out steps, did not perform steps in as objective a manner as the structured teams, and repeated steps. Unspecified teams tended to refer more to standard Estimate training materials, apparently seeking procedural guidance.

There was no additional advantage for the computer-supported teams over the structured teams as measured by quality ranking. Computer-supported teams that used a spreadsheet tool to aggregate numerical factors in a decision matrix avoided any arithmetic errors; each manual, structured team made one or more arithmetic errors. There were no significant differences in time or workload between the computer-supported and structured teams, even though the computer-supported teams only had about 2 hours exposure to the newly developed tools before using them.

The participants had difficulty in projecting war game results and in visualizing the battle. After the exercise, most participants felt that additional computer support would be beneficial for the task. Performance results on task steps identified potential targets for additional computer support: arraying forces to ensure that all combat power is taken into account; identifying and understanding critical events of a dynamic operation; and war gaming and projecting battle results.

The use of structured procedures in both the structured and computer-supported conditions identified shortfalls in the Estimate process. To reduce the chance of biased analysis, the standard Estimate training materials recommend that a COA not be selected until all COAs are independently evaluated and compared. Thirteen out of the fourteen teams came to a conclusion before the time the Estimate indicates is appropriate. No penalty was issued against those teams that made an early selection and no primacy bias was evident as five of the teams eventually switched to another COA.

The structured and computer-supported teams were required to compare COAs following a decision analytic or multiattribute utility approach. In this approach, each COA was assigned values on objective and subjective factors by the team. These factors were then weighted for importance and summed to give an overall figure of merit. There was very little difference between the two COAs on any of the objective factors for any of the teams. The teams seemed to load the subjective factors so the outcome would correspond to their COA "choice." The expert panel's solution also tended to lack much distinction using the linear, scaled, and weighted approach of multiattribute utility theory. It would seem that an a priori linear model of factors does not fit well with the highly interactive and probably uncertain aspects of the COAs. A more appropriate approach to distinguish between COAs was when the teams looked for information that suggested a COA would not be feasible or would have a greater chance of failing than another COA.

Utilization of Findings:

The findings have been used to highlight the existence of problems in the Estimate process: certain steps are not performed well (e.g., arraying forces); there are insufficient means to perform some steps (e.g., war gaming); and a linear, decision analytic model for selection is not universally applicable. These insights about the process have been used to make revisions to doctrinal materials on staff procedures and in C^2 lessons learned provided to Desert Shield commanders. The results of this study have also been used to identify human performance enhancement concepts for a prototype decision aid called the Operations Planning Tools (OPT). OPT is being considered for implementation into tactical data systems.

THE EFFECTS OF PROCEDURAL STRUCTURE AND COMPUTER SUPPORT UPON SELECTING A TACTICAL COURSE OF ACTION

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THE EFFECTS OF PROCEDURAL STRUCTURE AND COMPUTER SUPPORT UPON SELECTING A TACTICAL COURSE OF ACTION

INTRODUCTION

The Problem

AirLand Battle doctrine envisions a dynamic battlefield requiring initiative, agility, synchronization, and operations in depth. In order to keep pace with evolutionary changes in tactical doctrine, improvements in Army command and control (C^2) are required. Problems in tactical decision making stem from the battlefield environment, current C^2 procedures, and human capabilities and limitations related to information processing and decision making. The rapidly changing combat environment will impose severe time pressures on the staff and commander. Enormous amounts of information are available for commanders and staff officers, and there is little time to process this information for purposes of decision making. It is easy for humans to become overburdened as information changes rapidly and becomes more abundant. Though there is an abundance of data and information, uncertainties about the situation, goals, and outcomes will not necessarily be diminished. Time pressures, uncertainty, stress, and mental fatigue can adversely affect human performance.

Procedures for making tactical decisions are described in Army literature. In fact, the Estimate of the Situation has been accepted as the standard for decision making since 1909 (ST 100-9, 1989). Recent versions of the principal training documents on the Estimate have been called The Command Estimate (ST 100-9, 1989). The commander's estimate is defined as

> "the procedure whereby a commander decides how to best accomplish the assigned mission. It is a thorough consideration of the mission, enemy, terrain and weather, troops available, and time (METT-T) and other relevant factors. The commander's estimate is based on personal knowledge of the situation and on staff estimates." (p 1-17, FM 101-5-1, Hq DA).

More recently the training document is called Techniques and Procedures for Tactical Decisionmaking (ST 100-9, 1991). This report will refer to the process as the Estimate of the Situation or, just simply, the Estimate.

Despite the fact that the procedures for the Estimate were developed to be logical and analytical (Michel, 1990), staffs' and planners' own reports indicate that not all steps are followed. Consequently, only a portion of the decision making procedure may be performed, and the quality of the decision may be adversely affected. Overall, staff officers and commanders often do not have the time and capabilities to analyze courses of action in a systematic manner. The application of a systematic approach is challenged

by the complexity of the decision situations and procedures, relatively infrequent opportunities to train and practice, and the potential for lack of belief in the usefulness of the procedures.

One important consideration is to determine the usefulness of the procedures themselves. The Estimate implies that a decision analytic approach (or multi-attribute utility theory) is used for selecting among courses of action. The problem is that this approach may not fit all tactical problems. Tactical decision making is very complex in contrast to typical choice problems to which a multi-attribute utility approach have been confidently applied.

Work by Klein and associates (Klein, Calderwood & MacGregor, 1989; Klein & MacGregor, 1988; Thordsen, Galushka, Klein, Young, & Brezovic, 1990) and earlier work by Simon (1955) suggest that the best procedures are naturalistic ones. Their belief is that people need only develop a workable solution that satisfies their decision criteria or planning goals. Simon refers to this as "satisficing," as opposed to optimizing. Klein takes an even stronger view and proposes that the rapid decision making that characterizes experts is done on a recognitional basis. To an experienced decision maker, cues and expectancies set an immediate association to an appropriate response.

One reason that the decision analytic approach may not always fit the Estimate is that in tactical situations the real problem often is to determine what the goals and criteria are and to arrange them into concepts to accomplish the mission. This is the broader context of planning, as opposed just selecting among pre-established options.

The Estimate process is more applicable prior to a conflict when there are relaxed time demands. But once a tactical operation starts there are no established procedures to truncate or speed up the steps. Also the systematic procedures have been postulated to be applicable only to officers who are learning the process as a student in a formal course or as a newcomer to a staff. Further it has been speculated that the Estimate is too rigid and proceduralized for experts who can quickly size up a situation and who have a repertoire of responses to select from based on their knowledge of similar tactical situations. Writers of doctrine for C2 have suggested that the Estimate process has to be changed (or something different created to augment it) to apply it to ongoing battles where rapid planning and replanning are paramount and where it will be performed by an integrated staff with different specialties and experience levels.

Another approach to address performance problems with the Estimate is to devise computer assistance or aiding. There are certain activities, like retrieval of information from large data stores or arithmetic computations, that can be performed more quickly and accurately by computers while humans are more capable in other areas. A computer-based system could be used to relieve some of the staff officer's workload. This could allow the staff and commander to analyze a wider range of factors with the critical factors being examined in greater detail and depth.

Purpose and Rationale of the Experiment

To conduct research to assess human performance in tactical decision making, the Army Research Institute (ARI) Field Unit at Fort Leavenworth developed a laboratory test-bed called the Experimental Development, Demonstration, and Integration Center (EDDIC). For the current experiment, the EDDIC equipment and facilities were used to determine the effects of procedural structure and computer support on the performance of two members of an operations plan section (G3) who are required to analyze and decide upon tactical courses of action.

It was predicted that there would be performance differences between officers required to follow the estimate process and officers given only general task goals. This latter condition, referred to as manual unspecified procedures (or unspecified), was inserted into the experiment to represent conditions under which staff officers in the field currently plan. After receiving training in the estimate of the situation in branch and command and staff schools, staff officers are left to their own devices to apply the procedures in the field. Certain staffs might use more structured procedures than other staffs. By not specifying what procedures to follow for a group of experimental teams it was possible to observe what procedures were chosen and how they were followed.

We were unsure whether enforcing a structured estimate procedure would be better or worse than not specifying any specific set of procedures. The structured condition might be better if the officers in the unspecified condition did not remember a set of procedures or, if they made irrational, biased decisions which the systematic estimate process is supposed to discourage. The structured estimate process might be worse if it imposed procedures which the officers did not accept or if it did not support the dynamic nature of their tactical decision making.

Structured procedures were also of interest because in order to apply computer support to tactical decision making and planning, there must be some level of structure and consistency in procedures and reasoning on which to base the computer assistance. When this experiment was first contemplated, it was an accepted belief that active Army divisions differed in the way they did planning and decision making. So imposing structured procedures on officers given the task of analyzing courses of action serves both as a necessary precondition and a comparison to a computer-supported condition.

It was predicted that computer support supplemented with job and decision aids could reduce the level of difficulty and the amount of time associated with application of a structured approach to tactical decision making. This is predicted in turn to increase the quality of the decisions and the decision making process. The decision making procedures, job aids, and automated support were integrated into the Tactical Planning Workstation (Flanagan and Fallesen, 1990) and Course of Action Assessment Tool (COAAT) (Ross, 1989). The Workstation and COAAT were based on information, concepts, and procedures presented in U.S. Army literature (FM 101-5 and ST 100-9). Experience in other efforts of C^2 automation (Carter, Archer & Murray, 1988; Lussier, 1986; Michel & Riedel, 1988) was an important part of the development of these tools.

Experimental Treatment Conditions

The three experimental groups of teams are called unspecified, structured, and computer-supported. Participants in the unspecified group were allowed to perform the tactical decision making task using techniques and procedures of their choosing. Field-related experience as well as training received in the Command and General Staff College (CGSC) were undoubtedly influential factors. Teams in the structured group were provided a set of work sheets and job aids that encouraged a systematic approach to performing certain steps of the task. Step sequence and job aids were developed using concepts and principles outlined in Army literature (e.g., CGSC, 1989). Participants in the computer-supported group used the same procedures as did the participants in the structured group; however, computer-support was available to assist with certain steps of the task.

Experimental Hypotheses

Different outcomes of decision quality were considered possible from the efforts of teams in the three experimental conditions. It is difficult to predict all possible outcomes and process findings from the three conditions. Some potential outcomes and interpretations for various outcomes follow.

If the computer-supported condition produces the highest quality solutions, then it can be assumed that the computer-supported tools provide the most predominant benefit. Computer-support can be used to access information, to perform arithmetic calculations, to track and record intermediate steps, and so forth. Computers can provide rapid storage and recall of information. Computer support has the potential to augment performance by performing manual functions automatically and more accurately (e.g., arithmetic calculations). Computer information and menu selection can act as reminders to the user to be complete in decision making considerations. Since computers work with chunks of information, chunks resulting from the ongoing decision making process can be stored to keep a record of preliminary conclusions. An indirect benefit of computer-support can be to give the decision makers more time to consider a wider range of information and to allow completion of all steps of the task.

Computer-support does not automatically make performance faster; computers can take overhead in terms of data entry and control which manual tasks do not. If computer-supported approaches produce poorer solutions, then more training and familiarization might be required. Otherwise poor outcomes may be due to the computer tools impeding performance because of their inflexibility, invalidity, or some other characteristic. If the computer-supported solutions are no worse than good solutions from either or both of the other conditions, then one might predict that after more familiarization, the tools will improve performance to a significant degree. If the computer-supported tools were not used to perform the task, it would indicate a problem with user acceptance.

If the structured condition has the highest quality solutions, then it can be concluded that structured estimate procedures are favorable or that having a manual job aid to guide procedures is beneficial. If the solutions from the structured condition are worse than the unspecified condition, then this would suggest that the estimate was not the most effective set of procedures for the problem. Structured procedures might require longer times to perform the task because one step should be completed before going on to the next step. The steps are detailed and analytical to reduce the chance that biases will creep in and affect the conclusions. Time and workload measures will be compared across conditions to see if the structured procedures require higher workload than perhaps the more flexible unspecified procedures.

If the unspecified condition has the highest quality solutions, then it might be concluded that staff officers can efficiently tailor or adapt the estimate procedures to a problem at hand. If the unspecified condition produces better solutions than the structured conditions, but the officers in the unspecified condition use procedures which are very close to the structured ones, then this suggests that the mere presence of detailed guidance would detract from performance. If the unspecified condition produces better solutions with procedures different from the structured ones, then those new procedures can be used as candidate improvements.

Research Issues

This experiment addressed many additional research issues. The additional issues were used for diagnosis to understand any resulting differences among unspecified, structured, and computer-supported performance. Dealing with these supplemental issues allows a better understanding of information and decision making processes involved in analyzing and determining courses of action. Interface design issues related to the EDDIC system are also addressed. The following summarizes issues and questions addressed in this experiment.

- What computer experience do the participants have?

- What is the performance of the structured and computer-supported groups on each of the task steps compared to the expert panel.

- What information does the participants use in making a decision? What is the relative importance of that information?

- How adept are the participants at arraying forces and calculating combat power values and ratios?

- Do the participants appropriately identify and deal with critical events?

- How do participants war game (especially those in the unspecified group)? Can those using specified procedures follow the procedures? What objective and

subjective factors are considered important enough to use in war gaming? How sensitive are the war game estimates? What confidence do participants have in their war game estimates?

- How error-prone are the participants' arithmetic calculations?

- How are conclusions and selections made and justified? How thorough are they? Are they logical and consistent?

- How well can the groups adhere to the benchmarks for task and step times?

- Do the structured and computer-supported groups follow the structured steps or do they jump ahead and back, tend to be biased and arrive at conclusions before the proper step?

- How do the teams organize and manage their work?

- What kind of relationships are there between individuals on a team? Do the relationships affect performance?

- What level of knowledge do the participants have about the task and tactics?

- What style of performance (motivation, level of detail) do the participants follow? What are characteristics of the decision process (degree of analysis, stability, amount of confirmation)?

- How much have the participants perceived, learned, and retained about the scenario (mission, enemy, terrain, own troops, and time available)? Can incomplete understandings be tracked to performance outcomes?

- Is there a difference among types of workload? Does workload differ for different tasks? Does workload differ across conditions?

- What comments and suggestions do the participants have about the estimate task (COA analysis)?

- What suggestions do the participants have for supporting the task with automation?

- What is the level of problem solving abilities (as measured by the Complex Cognitive Assessment Battery) of the participants? How do they relate to performance on the task?

- How usable was the Tactical Planning Workstation and COAAT? What features were most desirable? What changes should be made?

METHOD

The first two subsections describe the selection criteria for participants in the experiment and the facilities and equipment used to support the experiment. The activities to develop and prepare the experiment and methods were extensive. The next section describes analytical and developmental activities that were required to identify the experimental task, develop the tactical scenario, identify the experimental conditions, develop automated tools, and determine the final experimental design by using findings from pilot testing. Experimental procedures are described in a methods section, and the final section addresses data collection and analysis procedures.

Participants

To minimize the possibility of inter-subject differences in knowledge and experience related to the experimental task, the following qualifications were established for participants:

- A rank of major or higher,
- A combat arms officer (infantry, armor, and field artillery),
- A graduate of the branch advanced course in their specialty area,
- A graduate or current student of the Command and General Staff Officers Course (CGSOC).

Participants were recruited as volunteers from officers assigned at Fort Leavenworth. Three sources of officers were drawn upon: faculty, staff, and students at the Command and General Staff College (CGSC); military analysts from the TRADOC Analysis Command; and CGSOC graduates awaiting order from the Combined Arms Command. To induce participation, officers were told about the experiment as an opportunity to solve military tactical problems and to comment on decision making procedures, manual job aids, and computer support.

From the outset, it became evident that the total number of participants would be unknown because of sporadic responses to the recruiting process. A total of 14 two-man teams were recruited. There were four teams for the unspecified condition and five teams each for the structured and computer-supported conditions. The background and qualifications of participants was not known prior to their arrival. Because of the intricacies of the computer condition and the extensive paper materials required, a treatment condition was fixed prior to the arrival of the participants. The participants could not be assigned to the conditions based on matching. A preset testing order (using balanced random strategy) was established for the experimental conditions. As participants became available they were assigned to each successive treatment condition.

Equipment

The following subsection describes the laboratory facilities in which the experiment was conducted and the computer systems used by the computer-supported group.

Laboratory Facilities

The experiment was conducted in the main laboratory of the Experimental Development, Demonstration, and Integration Center (EDDIC), a research facility of the ARI Field Unit at Fort Leavenworth, Kansas. There were differences in the configuration of the supporting facilities for the treatment conditions as shown in Figures 1 and 2; however, the following features of the facility supported experimental activities for all conditions.

The laboratory provided instrumentation capabilities to record the activities of participants. As a point of reference, the map board on the North wall was considered the front of the main laboratory. Two video cameras were permanently mounted on the side walls (east and west) of the main laboratory. These two cameras were remotely controlled from the observation room to pan and zoom about the laboratory while video and audio recordings were made on video cassette recorders located in the observation room. These video cameras also provided input to monitors in the observation room. Audio input to the recorders was accomplished from both fixed microphones in the laboratory and wireless microphones attached to each participant. These microphones ensured the best fidelity of the audio track on the video tape. A third video camera (with microphone) was tripod-mounted in the rear or south end of the main laboratory. This camera backed up the fixed cameras and also provided recording of exercise time plus a direct view of exercise activities at the north end of the main laboratory. This third camera had an automatic focus but no panning capability.

Direct observation of all exercises was performed by experimenter personnel. A moderator was present in the laboratory with the participants to give instructions and guidance. Observers were located at the rear of the laboratory in an observation room. One-way windows provided unobtrusive observation. Direct communication between experimenter personnel in the observation room and the moderator in the main laboratory was maintained by the use of a two-way radio communication system. Communications on this system were recorded manually in a moderator's log in the laboratory.

The equipment facilities also contained information (e.g., maps) and work spaces to support conduct of the experimental task by the participants. This support will be described later in this section.

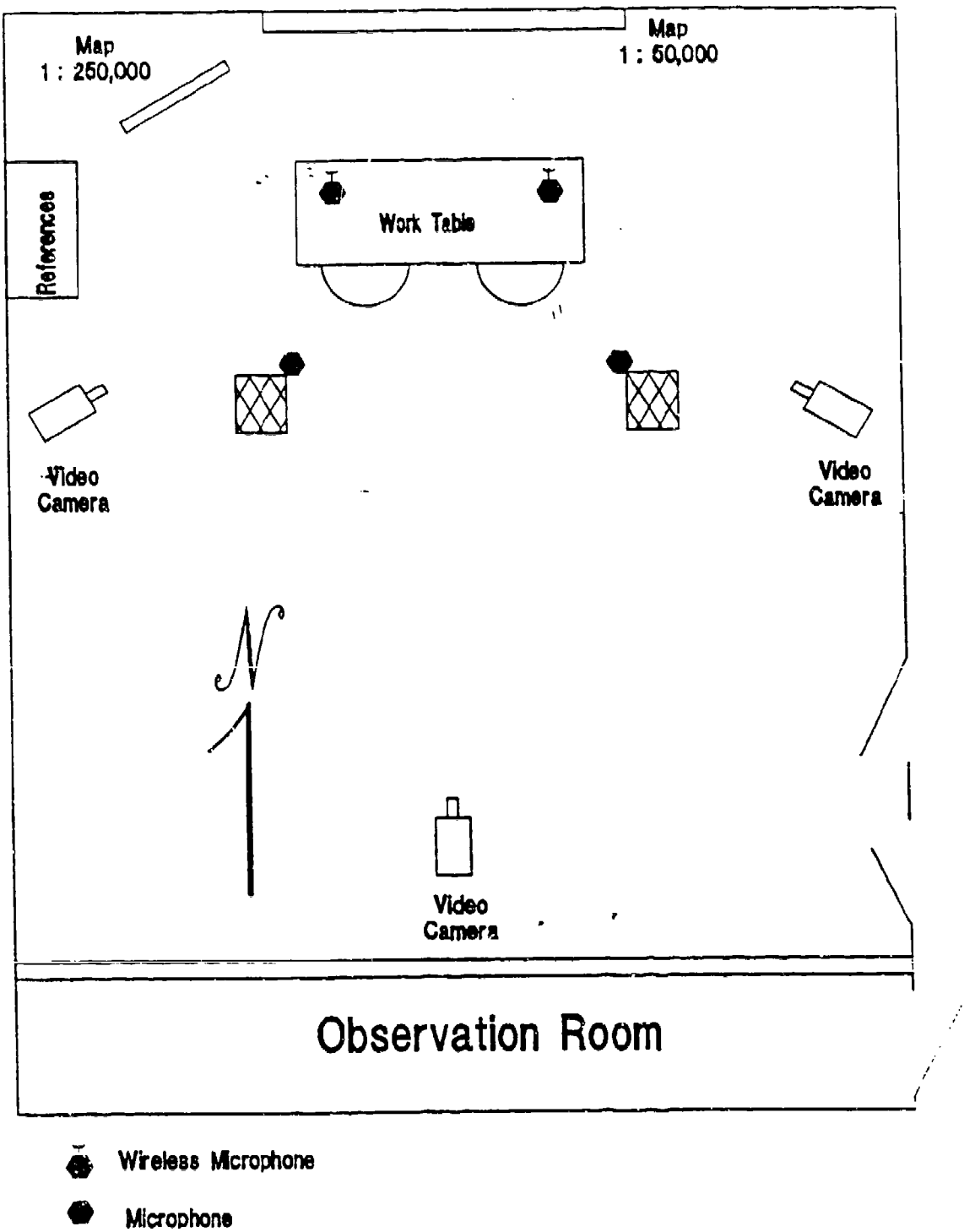

Figure 1. Experimental Development, Demonstration, and Integration Center (EDDIC) Main Laboratory (Manual condition).

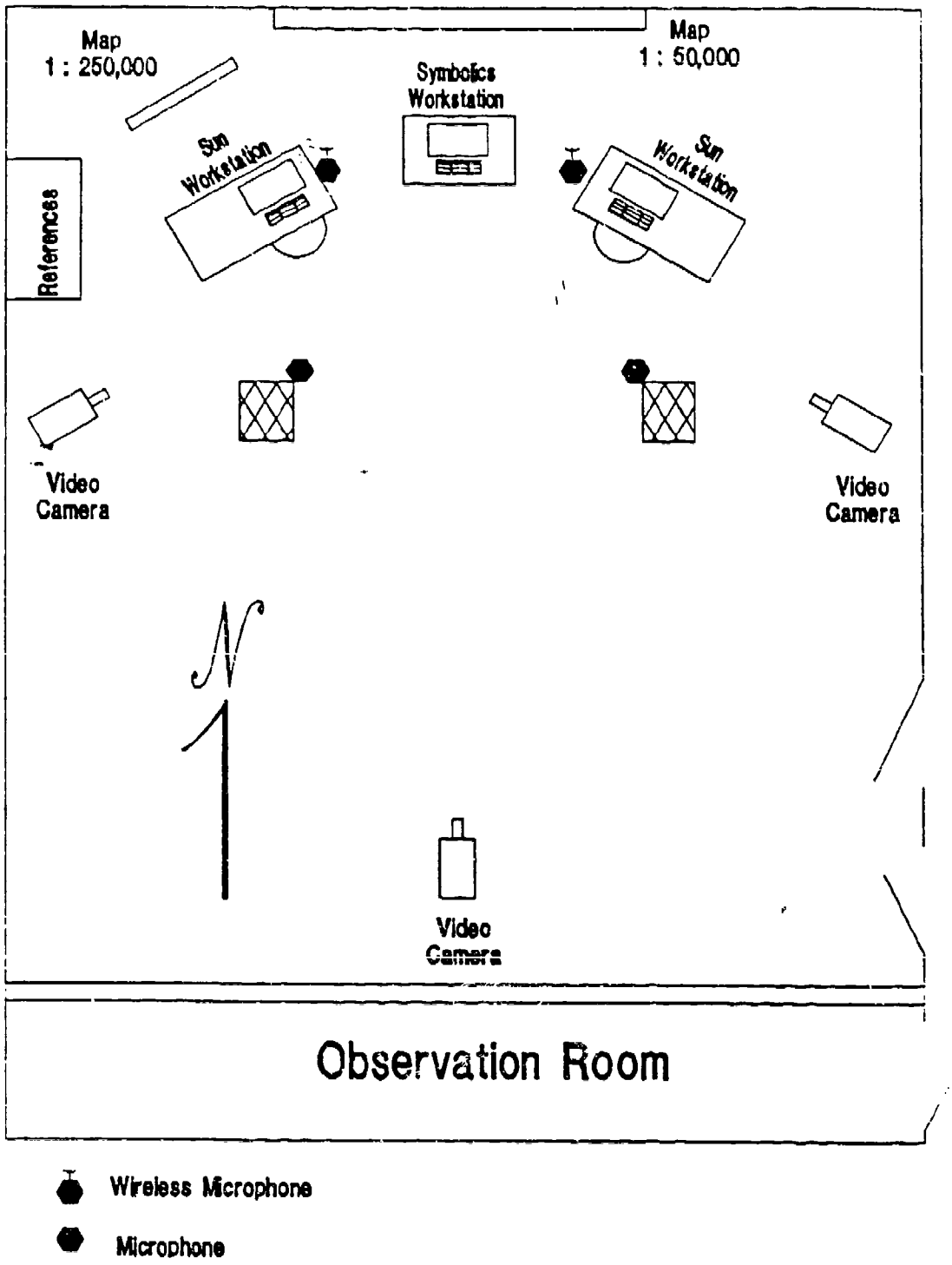

Figure 2. Experimental Development, Demonstration, and Integration Center (EDDIC) Main Laboratory (Automated Support condition).

Computer Systems and Network

Participants in the computer-supported group used two computer work stations to support performance of the experimental task (see Figure 2). The Tactical Planning Workstation software was hosted on a Sun 3/160C Color Sunstation (Sun Microsystems, Inc.) that included a high resolution 19-inch color monitor (1152 X 900 pixels). The software was programmed in Ada and C languages. A UNIX operating system was used. Participants used a keyboard or a three-button mouse to interface with the Tactical Planning Workstation. The decision aid called the Course of Action Assessment Tool (COAAT) was programmed in LISP and other symbolic languages to allow fast and efficient operation. COAAT was hosted on a Symbolics 3640 workstation. The Symbolics workstation had a high resolution, fully bit-mapped black and white screen, a keyboard, and a three-button mouse. The local area network (LAN) for computer systems was an Ethernet. This allowed for high-speed data exchange between information processing equipment in a moderately-sized geographic area.

Development of the Experimental Setting and Support

The Experimental Task

Identification of the experimental task was based on an extensive analysis that determined critical functions performed during tactical decision making at the division echelon (Carter, et. al, 1988). The content, organization, relative importance, and suitability of division-level battle staff functions was analyzed to determine how performance enhancement could be achieved through using computer support. The steps and sequential relationship of the functions were developed and then refined based on coordination with CGSC which is responsible for the development of Army tactical doctrine and with the Combined Arms Combat Development Activity (CACDA) (now the Combined Arms Command-Combat Developments) which is responsible for the C^2 mission area for the Army.

Based upon the analysis, the task of analyzing tactical courses of action (COA) was determined to be of greatest importance in tactical staff planning. The steps composing the task are diagrammed in Figure 3. The steps conform to doctrine enunciated in Army Field Manual 101-5, Staff Organization and Operations, (1984) and to material contained in USA CGSC Student Text 100-9, The Command Estimate, (1989) for the process referred to as preparation of the commander's estimate of the situation.

Tactical courses of action are often identified in plans or orders from higher command and/or from guidance given by the division commander. After basic tactical courses of actions are identified, planners must (a) develop an appreciation of the scenario and the current tactical situation and (b) identify the pertinent facts that will be considered when deciding upon the preferred course of action (see Step 2). The third step is to identify and list assumptions used to fill gaps in knowledge. The number of

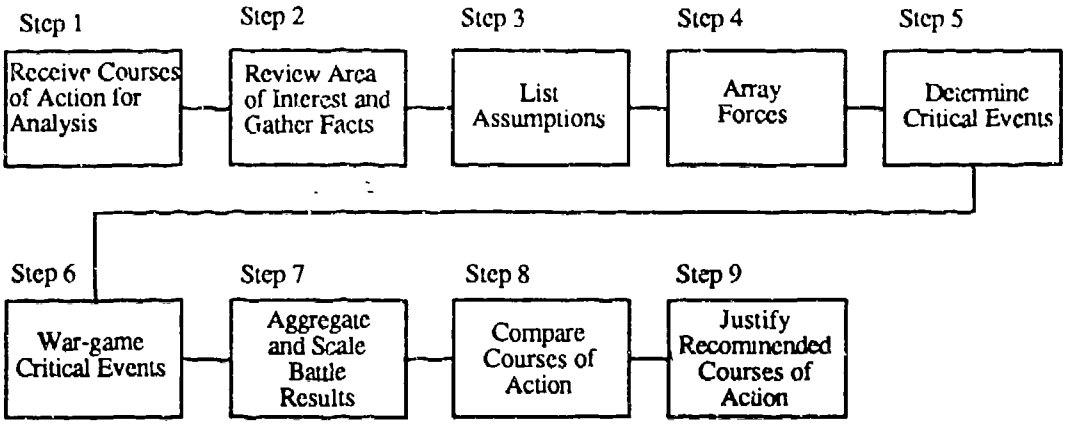

Figure 3. Steps of the experimental task of analyzing courses of action.

assumptions are generally kept to a minimum so that the basic task of operation planning is not "assumed away." Assumptions may be added, modified, or deleted as the analysis progresses, and each assumption should be validated before the analysis is completed.

During Step 4, planners array and task organize the friendly forces to perform the tactical mission under each alternative course of action. The force for each course of action should be organized with sufficient combat power to perform the assigned mission as well as be in conformance with the division commander's guidance.

In Step 5, planners identify and list critical events for each of the alternative tactical courses of action. Critical events are defined as those specified or implied battle tasks the completion of which are essential to mission accomplishment and which, in the judgment of the planner, required detailed analysis.

Step 6 starts the war gaming. For each critical event, the planners visualize the battle and estimate an outcome for critical battlefield measures (e.g., friendly casualties). After war gaming, they must aggregate or sum projected outcomes for each measure for all critical events (Step 7). At this point, the team compares the tactical courses of action (Step 8) and identifies the major advantages and disadvantages of each course of action (Step 9). As a general rule, advantages and disadvantages that are common to all courses of action should be disregarded since the staff is in the process of distinguishing between the courses of action. Similarly, advantages and disadvantages which are insignificant should be disregarded. When all of the significant advantages and disadvantages are identified and considered, a decision is made.

Tactical Scenario

The experimental task was performed in the context of a tactical scenario which provided participants with the situation and constraints for decision making. The scenario was a standard ARI scenario depicting a division-level offensive operation in Western Europe (Carter, Ross, & Michel, 1989; Fallesen, Michel, & Carter, 1989). The tactical scenario provided realism to the experimental setting and, more importantly, was a means to control independent variables representing a complex real-world environment. At the time of development, the scenario was based on standard information related to military organization, equipment, and tactical doctrine for simulated friendly and enemy forces. The scenario's geographic and climatic data were representative for the area of operations and season of the year. A mechanized infantry division was organized based on the J-Series table of organization and equipment (TO&E) (October 86 TRADOC update). The scenario was developed to accommodate exercise participation by two operations (G3) staff planners.

The tactical scenario included two tactical courses of action. The course of action with the main attack in the northern portion of the division zone is identified as COA N, and the course of action with the main attack in the south is identified as COA S. In order to avoid any bias which might arise from the order in which the courses of action were presented to the participants, for half of the teams COA 1 was identified as the course of action with the main attack in the north (counter-balanced condition A). In the other half, COA 1 was identified as the course of action with the main attack in the south (counter-balanced condition B).

The COAs were generated so that careful analysis by a team was required to increase the likelihood that the better COA would be selected. COA S had the heavier concentration of enemy troops (see Figure 4), and this situation could easily lead to a "gut reaction" that COA N would be favorable. Further analysis should reveal that COA N has a combination of terrain, enemy disposition, and lighting conditions which produces an unfavorable situation. At one point in COA N, friendly units would have to conduct a night river crossing against a "dug in" enemy.

Computer Support Capabilities

The human performance requirements of the experimental task were critical determinants of the types of computer support required to improve the timeliness and quality of decision making. The following describes tools that were developed and implemented.

Tactical Planning Workstation Tools. The Tactical Planning Workstation (Flanagan & Faliesen, 1990) provided tools to visualize the terrain using varied types of map displays, to visualize and reposition friendly and enemy units on a map display, to create and display tactical overlays, to access doctrinal reference and planning information, to access situational information, to create staff products, and to visualize

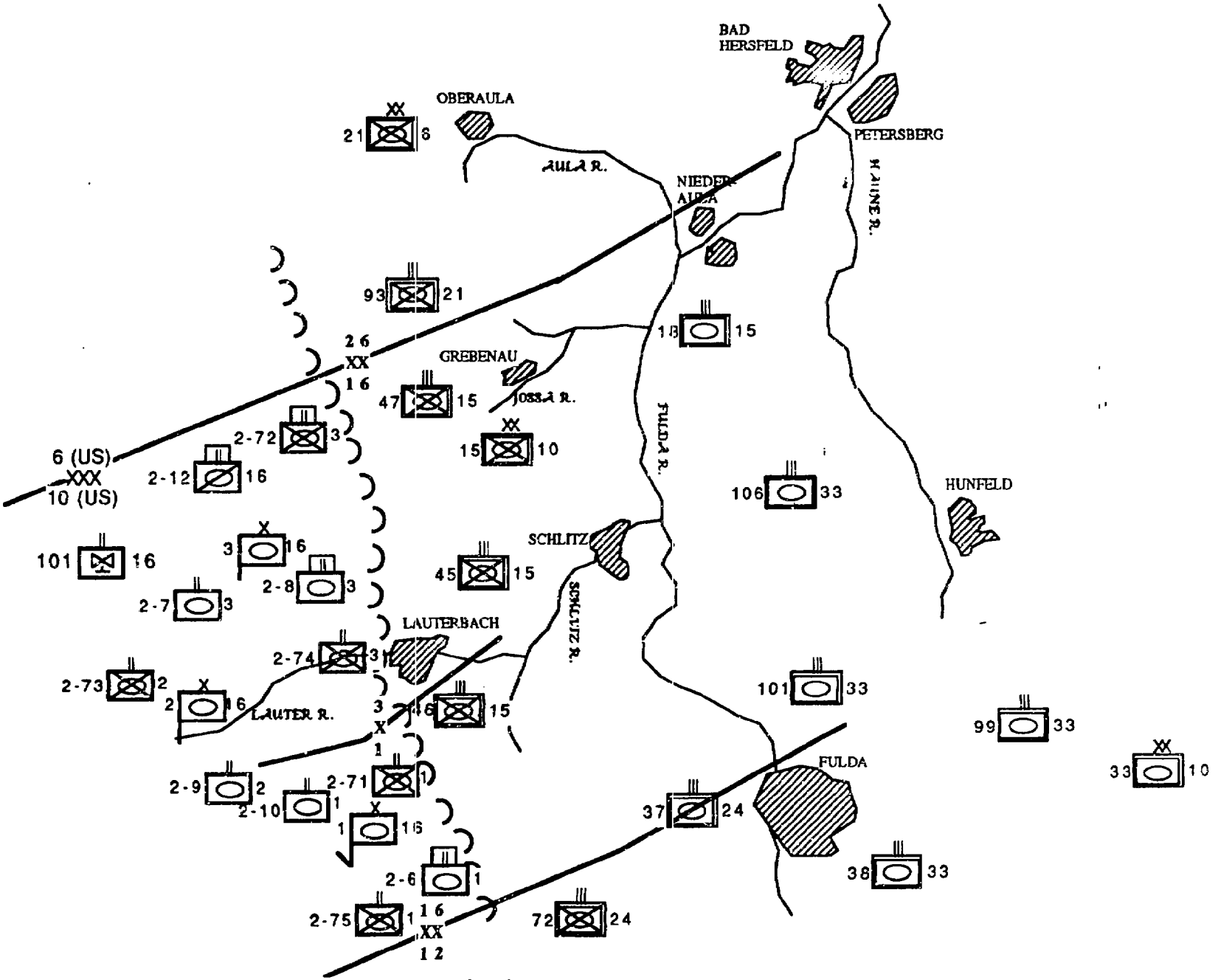

Figure 4. Offensive scenario: current situation.

the organization of units. The following summarizes some of the major functional capabilities provided by the workstation.

- View reference data: Tactical situation independent information from field manuals, technical manuals, tables of organization and equipment, and related sources.

- View situation data: Tactical situation dependent information that represents the battlefield situation.

- Build products: Formats or work sheets that guide the development of text products such as estimates and orders, and tools to support building of overlays.

- View terrain: Terrain representation using a vegetation background, shaded relief, and elevation banding.

- TOAST (task organization and status tool): Representation of task organization, unit status, and changes to task organization.

Course of Action Assessment Tool (COAAT). The COAAT, which resides on the Symbolics workstation, supports war gaming of alternative courses of action (Ross, 1989). COAAT consists of three modules used to assist participants in selecting and identifying the critical events for all courses of action, war gaming critical events, and comparing alternative courses of action. These capabilities are described in greater detail in the section that addresses participant activities during conduct of the experimental task.

Experimental Conditions

The experiment had three conditions. The conditions were:

- Unspecified: The team chooses how to perform the experimental task with reference and situational data available in notebooks.

- Structured: Experimental task is performed using prescribed steps and paper work sheets prescribed by the experimental protocol with reference and situational data being available in notebooks.

- Computer-supported: Experimental task is performed using prescribed steps and computer work sheets and spreadsheets provided by COAAT. Reference and situation data are accessible using the Tactical Planning Workstation.

Pilot Tests

Once the preliminary design of the experiment was developed, two pilot exercises were conducted using computer-supported conditions to verify the feasibility of the experimental paradigm and agenda. A major lesson learned was that participants could not be given unlimited time to complete the various steps of the process. As a result of these findings, it was necessary to impose time limits on certain steps or phases of the exercise to ensure that the exercise was completed in one working day. Imposing time constraints made it infeasible to test the experimental hypothesis dealing with time. Agendas were used to aid experimenters in the management of the experiment. Separate agendas were necessary for each experimental condition since conditions differed in level of structure and automation. For all conditions, each team was involved in experimental activities for a full working day (seven to eight hours).

Experimental Procedures

Experimental procedures varied with each condition; however, the following general sequence was followed. In the morning, a participant team received a briefing on the purpose of the experiment. Participants then completed a demographic questionnaire and a consent form. This was followed by a two-hour and 15-minute training program that varied across experimental conditions. After training, participants began the experimental task of analyzing tactical courses of action. Participants became familiar with the exercise data base (reference and situation) after which a workload assessment was conducted. Following a lunch break, participants completed the experimental task. Post-exercise data were collected. Participants completed another workload assessment, a situational awareness questionnaire, a COA task evaluation questionnaire, and, for the computer-supported conditions, a human-machine interface questionnaire. The exercise concluded with a debriefing of the participants. The following is a more detailed description of procedures.

Background Questionnaire

A background questionnaire (see Appendix A) was completed by each participant immediately upon reporting for the experiment. The participant was asked to provide information on his military education and experience, experience with computers and other computer-supported systems, and amount of staff training and experience.

Training

Performance of the experimental task by participants required various combinations of training in the following areas:

- Availability and organization of situational and reference material.

- Sequence and steps of the experimental task.

- Operation and use of job aids and computer-support.

The computer-supported condition required more training than the other two conditions to prepare participants to use the computer to support the task. As a result, it was necessary to provide comparable cognitive activities for the teams in the structured and unspecified conditions. This was achieved by having participants conduct computer based exercises using the Complex Cognitive Assessment Battery (CCAB) (Analytical Assessments Center, 1987).

The duration of the pre-exercise activities for all conditions was constant (approximately two hours and 15 minutes); however, the content varied by condition. Training under each exercise condition is described in the subparagraphs which follow.

Unspecified Condition. Participants used the self-administered CCAB to take nine CCAB subtests for a two-hour period. Exercise participants were then trained for 15 minutes on the availability and organization of situational and reference material presented in large loose-leaf-bound notebooks. The information was organized by staff functional area (personnel, intelligence, operations, and logistics), by broad data categories, and by detailed data elements. The volume was indexed for rapid retrieval of desired information.

Structured Condition. In this condition, the participants took five CCAB subtests for one hour and fifteen minutes. Experimental task-related training then occurred for the next hour. Using the same training provided in the unspecified condition, participants were familiarized with the availability and organization of situational and reference material.

The structured participants were then trained on the steps and structure of the task. The task structure was based on U.S. Army doctrinal publications and as taught in the Command and General Staff Officer Course. Training (and later, task performance) was based upon a series of explanations of successive steps in the task and upon work sheets used with each analysis step. A workbook provided participants with work sheets and a description of how to conduct each step of the structured process. A sample workbook is included in Appendix B. As the training ensued, the trainer used the workbook as a point of reference to discuss a process step, as well as situational and reference data necessary to perform the step. In this manner, the exercise participant was trained in an integrated fashion in both the process and the materials to support process performance.

Computer-supported Condition. In the computer-supported condition, the participants were trained in the same manner as were the structured teams. They were also trained on use of the Tactical Planning Workstation and COAAT embodied in the Symbolics workstation. They were trained on the availability and organization of situational and reference material in the Tactical Planning Workstation. Training on

situational and reference data bases focused on accessing information using walking menus and windows embodied in the Tactical Planning Workstation. Many of the work sheets to support war gaming (Steps 6, 7, and 8 of the experimental task) are represented by computer spreadsheets in COAAT. Training for the computer-supported condition required approximately two hours and fifteen minutes with much time being devoted to making the participants familiar and comfortable with the computer system. These participants did not receive exposure to CCAB.

Conducting the Exercise

Operation briefing. Conduct of the experimental procedures required the remaining portion of a working day for each team. At the beginning of the day, the team was briefed on strategic and tactical aspects of the scenario and of the requirements of the team. The briefing was also given in written form to ensure that all teams received the identical information. The participant teams were given an opportunity to ask questions about the introduction; however, answers were provided in strict conformance with the scripted introduction. When both members of the participant team had completed reading the briefing, a questionnaire was administered to the team members to ensure that they had retained critical information of the operation briefing. The team members were then debriefed by the experimenter, who provided the correct answers to the questionnaire.

The experimenter next read an extract of the division commander's planning guidance, and he answered any questions relating to the guidance. The division commander's guidance contained the two tactical courses of action which the participant team was to use for the experimental test. The full text of the commander's guidance appeared in the situational data base for the participants to refer to later.

Participants under the unspecified condition were not required to use a specified sequence of procedures to analyze tactical COAs; they were free to follow any structure they desired to perform the experimental task. If desired, participants of the unspecified condition could use doctrinal publications provided to them. The participants in the unspecified condition were only required to perform Step 9 of the structured procedures described below.

Select courses of action for analysis (step 1). The courses of action were included as key elements of the division commander's planning guidance. All participants were briefed on these courses of action by the experimenter at the start of the exercise. The courses of action could also be viewed by participants using the situation data base. In the experiment, the courses of action were provided to participants as a means to ensure experimental control. Without such control, a variety of courses of action could be advanced by participants, and analyses of these diverse courses of action would be exceptionally difficult, if not impossible.

Division Commander's Planning Guidance

As for courses of action, I want a strong initial attack supported amply by artillery, CAS, and attack helicopters. I also want a strong reserve positioned and prepared to quickly exploit our successes.

Consider COA 1 as two brigades on line with the main attack in the direction GREBENAU (NB3322), down the JOSSA River valley to crossings of the FULDA River in the vicinity of NIEDERJOSSA (NB4025), and on to the division objective. In this COA, I visualize a supporting attack on the axis LAUTERBACH (NB2809) - SCHLITZ (NB3913) - BURGHAUN (NB5116) to fix the enemy in position and to seize limited objectives.

For COA 2, consider two brigades on line with the main attack in the direction of LAUTERBACH - SCHLITZ - BURGHAUN and on to the division objective. In COA 2, I visualize a supporting attack on the axis GREBENAU - NIEDERJOSSA to fix the enemy in position and to seize limited objectives.

Review area of interest and gather facts (step 2). Access to situation and reference data bases allowed participants to "read up" on the tactical problem. Depending on the experimental condition, data could be viewed in either paper or on video displays. The situation data base provided scenario-dependent data for 24-hour time periods and at selected intermediate times as a means to represent battle progress. The situation data base included force and resource status information for both friendly and enemy forces as well as graphical and geographical information correlated in time with narrative information. While performing Step 2, the participant team developed a list of pertinent facts that were recorded on a work sheet (list of pertinent facts work sheet) for future reference. The situation and reference data bases could be revisited during the exercise, and pertinent facts could be added to the list by the participants at any time throughout the experiment.

List assumptions (step 3). It was necessary to guide and to maintain some control over conduct of the experimental task. For this reason, a list of assumptions was provided to the teams and the rationale for the selection of each assumption was supplied. Participants were told that the provided assumptions were the only assumptions to be used during the task. The participants were told to read and understand the assumptions and were to incorporate these assumptions into execution of the experimental task.

Array forces for each COA (step 4). For the friendly force, units were arrayed and task organized for the main attack, supporting attack, and reserve. In performing this step, the team should attempt to achieve a combat power ratio between friendly and enemy forces for the initial battle that will provide a fifty percent probability of mission success[1] as well as conform to the division commander's guidance. A task organization work sheet (structured condition) or computer spreadsheet (computer-supported

[1]For example, to achieve success in an attack against an enemy in a hasty defensive posture, the combat power ratio between attacker and defender must be 2.5:1 or better.

Planning Assumptions

Assumption	Rationale
1. No nuclear, biological, or chemical weapons to be used.	1. Neither combatant has used NBC weapons and no indications that the enemy will use them.
2. Bridges over the Fulda and Haune rivers will not be intact for friendly use.	2. The enemy in a hasty defense/delay will destroy major bridges to impose maximum delay.
3. 14 TA will not reinforce in less than 72 hours.	3. Intelligence indicates that the 14 TA is in assembly areas and is not moving. Preparation and movement will require at least 72 hours.
4. 313 Sep Mech Bde will not be available initially for employment.	4. Corps Commander has currently assigned a RACO mission to 313, but they may be available later.
5. 32 AD attack will be rapid and successful.	5. 32 AD is making the 10 (US) Corps main attack with significant combat power. Their success will prevent an attack on 16 MID southern flank.
6. 6 US Corps will occupy enemy on the North.	6. 6 (US) Corps will fully engage the enemy on 16 MID's northern flank.
7. 10 CAA will reposition the 33 GTD to counter the operations of the 32 AD.	7. With the Corps main attack being made by 32 AD in the south, the 33 GTD will be employed there and will not be committed against 16 MID.
8. Rain expected on 7 Sep will make Fulda river unfordable for 1-2 days.	8. Rain on 1-2 Sep raised the Fulda River level. More rain will probably make it unfordable.

condition) was used to record task organization or force allocation and the associated levels of combat power. In this experiment, task organization was constrained to units with combat power (i.e., maneuver battalions, attack helicopter forces, and supporting artillery units). The team next calculated the current combat power of friendly units and allocated the friendly combat power to the main and supporting attacks in sufficient quantity.

Determine critical events (step 5). From an analysis of the current battle situation, the participant team identified critical events for the main and supporting attacks for the two COAs. A critical event assignment work sheet or a computer spreadsheet was used to record a critical event identification number, the type of critical event, the objective, and comments. Participants were provided with a list of candidate critical event types (e.g., cross river, seize objective, penetrate first defensive belt) to aid in event identification; this list provided a job performance aid for identifying critical events and allowed for greater standardization in the types of responses from participants. Participants also classified critical events into the factors of mission, enemy, terrain and weather, troops, and time available (METT-T). Each critical event was

"circled" either on the map board with a grease pencil or an automated tool available within the Tactical Planning Workstation.

War gaming critical events (step 6). At the onset of this step, the moderator provided the structured and computer-supported teams with a list of pertinent facts, an array and an allocation of combat and combat-support forces for each course of action, and a list of critical events for each course of action. These materials, together with the list of assumptions provided during Step 3, constituted a baseline for continuing the experimental task. Without these experiment controls, the variety of war gaming alternatives offered by the teams could make data scoring and analysis very difficult, if not impossible. The following description of Step 6 applies only to the structured and computer-supported conditions.

Teams were asked to visualize the battle for each critical event (for main and supporting attacks for each COA) in order to predict battle outcome for selected measures. Eight battle outcome measures were offered to the participant team, and any of these could be used by the team for war gaming. The measures provided to the teams were friendly and enemy personnel losses, friendly and enemy equipment loses (major end items), percentage of POL expended, percentage of ammunition expended, FEBA movement (km) for the main attack, and battle duration (hours) for the main attack. Teams were allowed to provide battle outcome estimates for three phases of each measure for a critical event: actions before the actual critical event, actions during the critical event, and actions taken upon completion of the critical event (e.g., consolidation).

In performing the war gaming activity, the participant team for structured and computer-supported conditions completed either critical event war gaming work sheets or computer spreadsheets (Module 2 of COAAT), for each critical event for the two COAs. The work sheet identified the critical event being gamed, divided the critical event into three standard phases, and offered the eight war gaming measures for assessment of battle outcome. If the team provided battle outcome estimates for the three phases of each critical event, then COAAT automatically summed the estimate for the phases. The team had to perform their own addition for the structured condition.

Aggregate and scale battle results for each COA (step 7). After war gaming, the results for each course of action were aggregated and scaled using the war gaming summary work sheet or a computer spreadsheet. For each of the battle outcome measures, the following procedure was used. The team first summed predictions for all critical events for both the main attack and supporting attacks for each COA. The values for main and supporting attacks were then added for each COA. A Scaling Factors Table was then used to rate the "goodness" of each measure using a scale that ranged from 1 to 9 where high values were considered "acceptable or good" results and low numbers were considered "unfavorable" results. This summation and scaling process was conducted on all battle outcome measures for each course of action. Summation and scaling were done manually for the structured condition while COAAT automatically performed these functions under the computer-supported condition.

Compare courses of action (step 8). To this point, the team has predicted battle-outcome measures that could be objectively measured during an actual combat episode. The team is now at the point of considering more "subjective" factors that could contribute to success or failure of a mission. Five subjective measures were provided to the team by a COA comparison work sheet (manual structured) or a computer spreadsheet (computer support). These job performance aids also provided the capability for the team to include three more subjective measures if so desired. The work sheets and spreadsheets also contained the eight objective measures considered during Steps 6 and 7.

The next activity in this step was to independently weight both battle-outcome (objective) and subjective measures. The weight assigned should reflect the relative influence of that measure for each course of action. Objective and subjective measures may be weighted as independent categories, or they may be lumped as a single category. The measure with the greatest influence on the selection of a preferred course of action as determined by the participants was weighted highest. All other factors were then weighted in relationship to the most important factor and receive a weight less than that factor.

The next activity in this step was to scale the subjective measures for goodness using a scaling table that was provided. The participant scaled only those subjective measures which were considered when comparing the alternative courses of action. Scaled values were entered in the COA comparison work sheet. COAAT automatically performed that function for the computer-supported condition.

Finally, the weight and scale value for each objective and subjective measure were multiplied. Then the product of all battle-outcome measures were added to produce a grand sum for the objective measures. A similar grand sum was obtained for subjective measures. Mathematical computations were performed automatically by Module 3 of COAAT for the computer-supported condition.

Justify recommended COA (step 9). All teams used a COA selection and justification work sheet to record advantages and disadvantages associated with the two COAs. This work sheet could be used by the team as a job aid in making their decision. The participant teams were advised to analyze and evaluate the advantages and disadvantages by a technique of their own choosing and to produce a narrative which compares the courses of action. The narrative should have been in sufficient detail to convince the commander of the preferred (recommended) course of action.

Workload Assessment

The participants' perception of workload imposed by the experimental task was assessed using the NASA Task Load Index (NASA-TLX) (NASA Ames Research Center, 1986). This assesses mental demand, physical demand, temporal demand, performance, effort, and frustration associated with task performance. Definitions of

these dimensions of workload and work sheets were provided to participants. In each of the structured exercises (manual and computer-supported), a workload assessment form was distributed to participants twice during the exercise, once after performance of the first three planning steps and again at exercise completion. In the unspecified condition, workload assessment was also performed twice; however, its performance was not linked to specific analytical steps of the task but was scheduled at a time of the exercise comparable to when workload was assessed for the other two conditions.

Post Exercise Procedures

A variety of performance data was collected following conduct of the experimental task. The following subparagraphs describe data collected using the Situation Awareness Questionnaire, the COA Task Evaluation questionnaire, the Human-Machine Interface questionnaire, and the after-exercise debriefing.

Situation awareness questionnaire. There are many items of scenario information in the situation data base which should be considered by the participant team in performing the exercise. The objective in administering this questionnaire was to determine the extent to which the participants have an adequate and accurate understanding of the tactical situation. A questionnaire of 32 items was designed to sample the extent of knowledge of key tactical information. The multiple choice questionnaire required approximately ten minutes to complete. A copy of the situation awareness questionnaire is presented and summarized in Appendix C.

COA analysis task evaluation. The COA Analysis Task Evaluation questionnaire was used to examine factors related to how the participants conducted the analysis of courses of action. All participants were asked for their priorities of information sources, the step when in the process when a decision was made, and the level of difficulty associated with the various steps and decision making activities. Participants in the structured and computer-supported conditions were asked about their level of confidence in estimates of war gaming measures and their understanding of the reason for scaling the war gaming factors. Appendix D presents the COA Analysis Task Evaluation questionnaire.

Human-machine interface evaluation. This questionnaire (see Appendix E) was presented to participants exposed to the computer-supported condition. Questions were asked on issues such as the ease of access to data sources, the most useful attribute and features of the map display, and other questions related to ease of operation of both the Tactical Planning Workstation and COAAT.

Team profile. A team profile work sheet was used by data collectors to organize their notes related to work management, team dynamics, performance style and strategy, performance results, and use of media. Notes were based on observation of participant performance throughout the conduct of the experimental task. Appendix F presents the team profile work sheet.

Performance Measurement and Analysis

The Measurement Challenge

One of the biggest challenges of this experiment was the identification or determination of performance measures and criteria. Analyzing tactical courses of action relies heavily on information management and cognitive processing; both of which are difficult to quantify and assess. There is a prescribed process for analyzing courses of action; however, the outcomes are not always well-defined and standards of performance do not exist. By definition courses of action need to be feasible; if not, then they are dropped from consideration and no longer constitute a COA. The COAs for this experiment were developed so that it would be difficult for the planners to distinguish between them. The final product for the experimental task required a recommendation on a course of action; however, there are no absolute right or wrong answers to this tactical problem.

Assessment of decision making processes and products was done using **direct** and **indirect** performance measures. Direct measures were based on measurable performance during conduct of the experimental task; these measures were used primarily to test research hypotheses related to the quality of processes and products. Indirect measures were based on data collected using questionnaires and observation sheets completed by participants and observers, respectively. Indirect measures were used to test workload-related hypotheses and secondary research issues, and to provide insight into the reasons why direct measures of performance came out as they did.

Data requirements and performance measures were developed for process steps and the final products for the tasks. Use of an expert solution to the tactical problem was the primary means to establish a baseline level of performance for the participants. The following provides a description of the expert solution, direct measures, and indirect measures used in this experiment.

The Expert Solution

An expert solution to the tactical scenario was used as a benchmark from which to measure the performance of teams participating in the experiment. Two expert teams/panels from CGSC, (each team consisting of two subject matter experts) participated in the development of an initial expert solution. The expert teams actually had to solve the same tactical problem presented to the participants in the experiment. Following development of the solution by the expert panels, an additional panel consisting of military-experienced contractor personnel and a psychologist from the ARI Field Unit was convened to fine-tune the expert solution to meet scoring requirements of the experiment.

Even though the expert solution was used as a benchmark, certain inherent limitations are recognized. The expert solution is just one possible solution developed by a small number of "experts." One should recognize that other solutions may have equally served as a benchmark.

Direct Measures of Performance

Direct measures of task processes and products were assessed using the expert solution as a benchmark to determine (a) the number (or percentage) of item matches with the expert solution and (b) the amount of deviation (i.e., a difference score) of the participant team's score from the expert score. The following describes data summary and analysis procedures used to assess decision making performance.

Review area of interest and gather facts (step 2). For analysis of Step 2, the list of pertinent facts provided by the participant team was compared and evaluated against a similar list prepared by the Expert Panel. The expert solution identified 24 facts pertinent to the exercise performance. The pertinent facts selected and listed by the participant team were grouped by METT-T category and were compared to the expert solution by relating key words and phrases. Each fact was scored as a match or no-match. Each METT-T category was evaluated for matches; however, the aggregate score for this step was a percentage of total matches by the participant team. The scoring for this step was performed by the expert scorer. In the scoring, no credit was given for facts in addition to those identified by the expert panel, the rationale being that any other facts were of secondary importance.

Array forces for each COA (step 4). Analysis of combat power (CP) measures provided an indicator of how effectively the team arrayed their forces to achieve an acceptable probability of mission success. The combat power allocation resulting from arraying of forces by the expert panel was used as the point of reference for assessing how effectively the participant teams arrayed their forces. The following combat power measures for the friendly force were calculated:

(a) Main attack difference score = (expert panel main attack CP) - (participant team main attack CP)

(b) Supporting attack difference score = (expert panel supporting attack CP) - (participant team supporting attack CP)

(c) Reserve difference score = (expert panel reserve CP) - (participant team reserve CP)

(d) Array deficit = (total available CP) - (arrayed CP)

(e) Total array error = |main attack difference score| + |supporting attack difference score| + |reserve difference score|

The teams arrayed forces for the main attack, the supporting attack, and the reserve for both COAs; however, the primary focus was on the main attack (main attack difference score), for if the main attack did not succeed, then mission would probably not succeed. The array deficit was used to indicate the degree to which the team used all available resources. And finally, total array error indicated the total amount of error the team achieved relative to the expert panel. If, in arraying the forces, the participant team simply selected and arrayed the forces and did not compute combat power scores and combat power ratios, the scorer determined combat power allocations resulting from the force array generated by the team.

Determine critical events (step 5). Scoring analyzed the critical events identified by the team that matched critical events identified in the expert solution. A match required the participant team's critical event to both (a) be of the same description (type) and (b) be located within three kilometers of center of mass of the critical event identified in the expert solution. Matches and non-matches were determined for each team and group means were used for analysis.

War game the courses of action (steps 6 and 7). Eight battle outcome measures were presented to the participant team to assist in assessing battle outcome of each critical event, but teams were not required to consider all measures during war gaming. For purposes of scoring, only the three measures corresponding to the expert solution were scored (the other five measures being of secondary importance). Two of the measures scored (friendly equipment losses and enemy equipment losses) contributed directly to combat power because they represented major weapon systems. The third measure scored was battle duration. For each experimental condition, the mean and standard deviation of predicted measures was determined.

Compare courses of action (step 8). The bases for comparing courses of action are the weights and scales assigned to each measure. Each objective and subjective factor analyzed by the teams was assigned a weight and scaling value. For each objective factor, multiplying the weight by the scale gave a single score for that factor. The sum of products for all objective factors gave a single aggregate measure for objective factors. A single aggregate measure was also generated for subjective factors.

Justify recommended COA (step 9). Several scoring approaches were considered for analysis of the decision justification. One obvious method is to count those teams selecting the same COA as the experts as correct and the teams selecting the other COA as incorrect. Although the selection of the COA was important, the selection itself does not sufficiently distinguish the quality of reasoning. Credit for only the correct solution would not distinguish between those teams "chancing" upon the expert-selected COA and those appropriately considering many aspects of the situation - but selecting the non-expert COA (because of attention to different factors of importance).

A second method for scoring is to score solutions based on agreement with the factors and rationale used by the experts. The expert solution identified specific advantages and disadvantages of each course of action. The advantages and

disadvantages developed by the participant team were compared by the expert scorer to those of the expert solution. The significant factors identified in the expert solution were weighted from 1 to 5 as shown in Table 1 where a value of 5 indicated the most significant factors. This approach to scoring is similar to a multi-attribute utility approach.

A third approach focuses on the merit of the team's justifications based on a select set of factors. The reasons for choice and severity of errors were of interest for the merit of justifications. This approach focuses on the essential elements distinguishing between the two COAs in terms of feasibility and risk. It does not presume that the essence of the comparison, selection, and justification can be adequately done as an enumeration strategy. This approach considers that choices involving complex options are more naturally and efficiently made by elimination by aspects, satisfying minimal choice criteria, or strategies other than multi-attribute utility.

All three approaches were used and are reported in the results section. The major scoring and analysis effort went toward the third approach. The rationale used by the experts for making the choice boiled down to the following.

The greatest distinction in the feasibility of the two COAs accomplishing the mission was that COA N required an opposed river crossing. The second echelon, enemy reserve 15 MRD, would be expected to be in defensive positions on the far side of the Fulda River. The Fulda crosses the Northern avenue and was unfordable with only limited bridging assets available to the friendly forces. In the South the Fulda was fordable and the enemy second echelon would have to move out of their defensive positions to encounter the friendly forces. While moving, the enemy could be engaged and attrited by close air support (CAS). In their dug-in positions at the Fulda they would not be as easily attrited.

These significant factors were operationalized for scoring in the following way. Teams correctly identifying the existence of the second echelon, their location, and their posture (or capability) would be given four points. If a team recognized that they were faced in the North with a river crossing over an unfordable river with limited bridging assets they were given 3 additional points. The second echelon opposition force was considered to be more critical than the requirement to do the river crossing. Points were reduced for partial assessments. For example, if teams correctly identified the existence of the force but misinterpreted their location at encounter or defensive posture the score would be reduced by 2 points. The recognition of limited bridging (at a minimum, implying the perceived requirement to do a river crossing of an unfordable river) would attain 3 points. If the river was identified as unfordable then 2 points were awarded, and if only the need to do the crossing was identified they were awarded 1 point. Points for opposition and river crossing considerations were summed for a maximum of 7 points.

Table 1

The expert panel's weightings for critical mission factors considered during COA justification

METT-T Factor	Mission Factor	COA Favored	Weighting
Own troops	River crossing operation	South	5
Terrain	Major river obstacle	South	5
Enemy	Encounter enemy second echelon	South	4
Time	Battle duration	South	4
Enemy	Encounter enemy first echelon	North	3
Own troops	Major friendly equipment losses	South	3
Terrain	Avenue of approach restrictions	South	3
Terrain	Lines of communication	North	3
Mission	Accomplish the mission	None	3
Enemy	Enemy equipment losses	South	2
Terrain	Major city obstacles	North	2
Own troops	Engineer bridging	South	2
Own troops	Force positioning	South	2
Own troops	Protect flanks	South	2
Terrain	Distance to objective	None	1

Indirect Measures of Performance

There were a number of data collection instruments used to collect data that contributed to the interpretation of a team's performance on the experimental task. Table 2 summarizes the types of data collected with each instrument and how the data were used.

Table 2

Indirect data collection instruments, data collected, and purpose of the data

Data collection instrument	Data	Purpose of data
Demographic questionnaire	Information on background and experience related to: formal military training and unit experience, unit experience related in the Fulda Gap area, and use of computers.	To confirm required background and experience of participant, to confirm that experimental groups had comparable backgrounds and experience, to relate background/experience and tactical decision making; to relate past computer background and experience with performance measures associated with decision making.
Operational briefing questionnaire	Answers to questions covering critical aspects of the tactical operations briefing.	To assess understanding of the tactical situation and to use results to provide feedback ensuring an adequate understanding of the problem. (Data are not presented in this report.)
Computer-based Complex Cognitive Assessment Battery (CCAB)	Performance data on complex cognitive abilities (unspecified and structured groups only).	To demand perceptual and cognitive pre-exercise activities that are comparable in complexity and duration across all exercise conditions; to assess cognitive and tactical decision-making abilities.
Situational awareness questionnaire	Answered questions covering knowledge of critical METT-T information as contained in the situation data base.	To assess how accurately the participant assimilated and retained key information about the situation.
Workload assessment questionnaire (i.e., the NASA Task Load Index (TLX))	Self-rated perceptions of workload experienced during performance of the experimental task.	To assess the impact of structure and computer support on perceived workload.

Table 2 (continued)

Data Collection Instrument	Data	Purpose of data
COA task evaluation	Participant provided opinions/judgment related to: the situation and reference data bases used in performing the COA analysis, how difficult it was to perform each step, when the preferred COA was selected, confidence associated with certain estimates required to perform the task, confidence that the procedures followed were valid, and comments on the structure and work sheets.	To facilitate understanding of the how and when the decision was made, to provide feedback to improve the structured approach and associated work sheets.
Team profile	Recorded observations by researchers on issues associated with work management, team dynamics, performance style and strategy, results of team performance, and media used to accomplish the task.	To facilitate understanding of the processes used to perform the experimental task; to support an assessment of the relationship between team behavior and product quality and timeliness.
Human-machine interface evaluation	User responses on interface design of the Tactical Planning Workstation.	To facilitate interpretation of results related to task automation; to receive recommendations on how to improve future versions of the Workstation.

RESULTS

The results are presented in four major subsections. The first provides an overview of the characteristics of the participants. The second subsection describes results for task performance related to the various steps or phases of the experimental task. The third subsection discusses the task processes in more detail. And finally, results are presented on participants' responses to questions about the tasks and the computer-support.

Description of Participants

A summary of the demographic data is presented in Table 3. There was a total of 28 participants in the experiment. While prerequisite criteria were established for participants, no individual was excluded from the experiment because of failure to meet the criteria. Participants were not dismissed because they were extremely difficult to obtain. All but one of the participants met at least three of the four selection criteria for the experiment (rank of major or higher, combat arms officer, branch advanced course graduate, and student or graduate of CGSOC). Twenty-seven participants were of a rank of major or higher; one participant was a captain promotable.

For data analysis purposes, teams were given unique designator codes. These are used in the first column of Table 3. The first letter indicates whether the team was in an unspecified (U), structured (S), or computer-supported (C) condition. The second letter indicates whether the first COA mentioned in the Commander's Guidance was COA N (A) or COA S (B). The numbers indicate the sequence in which teams were tested. For example, SA08 refers to a structured condition with COA N presented first and the eighth overall team.

Nineteen of the 28 participants were from combat (C) or combat support (CS) branches. In the unspecified condition, five were from C/CS branches and four from combat service support (CSS). The structured and computer-supported conditions each had seven C/CS participants and three from CSS. There were no significant differences among the groups' task and tactical knowledge as judged by the experimenters (Chi square=2.77, α=.25) from observation of performance.

All participants were graduates of an advanced course. All but two participants were CGSOC graduates. The two non-CGSOC graduates (CA05, see Table 3) had just completed the first trimester of the course. One participant was a graduate of the Army War College and another was a graduate of the Armed Forces Staff College. Three participants completed both the nonresident and resident modes of CGSOC. Three participants completed only the nonresident mode of CGSOC.

There were no significant differences in the number of command positions held by participants among experimental conditions (Kruskall-Wallis statistic=1.25, α=.54). Nor were there any differences in the number of staff positions (Kruskall-Wallis

Table 3
Participants' background characteristics

Condition	Rank	Branch	Years in Grade	Years in Serv.	High Educ.	Major	Year of CAS3	Year of CGSC	Postions in Cmd	Postions in Staff
UA01	LTC	CSS	3½	22	MA	Urban Studies	-	79	1	0
	MAJ	CSS	6	17	MA/MS	Int'l Relat. Trans. Mgt.	-	90	0	2
UB04	COL	C/CS	¼	24½	BA	Management	-	82[1,2]	3	3
	LTC	CSS	1	18½	MS	Logistic Mgt.	-	83[2]	1	3
UB09	MAJ	C/CS	4	15	MA	Pol. Science	84	90	1	3
	CPT	C/CS	6½	11½	MA	Construction	83	90	2	4
UA11	MAJ	C/CS	1¼	13	ME	Civil Eng.	84	90	2	2
	MAJ	CSS	6	17	MA	Business	82	90	1	3
Averages:			3½	17½					1.4	2.9
SA03	MAJ	C/CS	2	13	BS	Engineering	-	85[3]	3	4
	MAJ	C/CS	4½	16	BA	-	-	89[3]	2	4
SB06	MAJ	CSS	6	16½	MA	Marketing	-	88	0	6
	MAJ	CSS	6	18	BA	Business	81	86	0	3
SA08	MAJ	C/CS	3	14	MEd	Psychology	83	90	1	3
	MAJ	C/CS	6	17	BA	Secondary Ed.	-	90	0	3
SB12	MAJ	C/CS	1	16	JD	Law	-	90	3	3
	MAJ	C/CS	3	14	MS	Physics	83	90	1	2
SA13	MAJ	C/CS	4½	14	MA	Engineering	-	90[4]	2	3
	MAJ	CSS	5	16	-	Journalism	-	90[5]	1	0
Averages:			4	15½					1.3	3.1
CB02	LTC	C/CS	¼	19	MS	Engineering	-	85	1	9
	LTC	C/CS	¼	18	MS	Engineering	-	84	2	7
CA05	MAJ	C/CS	1	12½	MBA	Finance	-	90[6]	1	2
	MAJ	C/CS	1	12½	MS	Info. Systems	-	90	3	3
CA07	MAJ	CSS	4	15	BS	Art Education	-	89	1	4
	MAJ	CSS	5	16	BS	Social Res.	-	89	1	4
CB10	MAJ	C/CS	4	15	MA	Military Eng.	-	90	3	4
	MAJ	C/CS	3	14	MBA	Business	-	90	1	3
CB14	MAJ	C/CS	5	15	MA	Engineering	-	90	3	3
	MAJ	CSS	-	14	BS	History	-	90	2	1
Averages:			2½	15					1.8	4.0

[1]Army War College - 1990
[2]Armed Forces Staff College - 1984
[3]Nonresident course
[4]Also nonresident CGSOC - 1981
[5]Also nonresident CGSOC - 1985
[6]Selectee for SAMS

statistic=1.50, &=.47). All participants had command or staff experience. All but one participant had staff experience (an average of 3 assignments per participant). Twenty-four participants had held command positions (an average of 1.6 positions per participant). Fifteen of the twenty-four participants' commands were in combat arms or combat support. Division staff experience among the participants included an assistant G3 and DIVARTY in the computer-supported condition; deputy G1/AG in the unspecified condition; and G3 training, G1, deputy G4, G3 plans, and EW/OPSEC in the structured condition.

Table 4 shows responses to computer experience questionnaires. There were no significant differences among experimental groups on whether participants had taken computer courses, had used computers with a cursor, had done programming for themselves or others, or computer ownership (Chi Square = 4.48, &<.25). There was no difference in the frequency of computer usage among the participants of the three groups (Kruskall Wallis statistic=3.66, &=.16).

Requirements were relaxed to include any branch when participants became available. There were no differences on indicators that cast doubt on the similarity of the groups.

Task Performance

Courses of Action (Step 1)

Courses of action (COAs) were provided to the teams through the Division Commander's guidance. No measures were taken in this step.

Pertinent Facts (Step 2)

Participants became familiar with the scenario and gathered pertinent facts using the situation and reference data bases. The expert panel identified a total of 24 pertinent facts and this was used in comparison with the structured and computer-supported teams.

The numbers of teams recognizing and mentioning facts are given in Table 5. Participants in the unspecified condition were not required to list pertinent facts. For comparison to the structured and computer-supported groups, the content of their discussions was analyzed for mention of any of the pertinent facts previously identified by the experts. The proportion of pertinent facts identified did not differ significantly among the experimental groups. The groups identified an average of only 22 percent of the pertinent facts identified by the expert panel. (The teams in the structured and computer-supported conditions received the expert panel list of facts after they had completed this step.) The facts which were not identified (narrowing of zone, poor cross country movement, required loads of ammunition and POL equal basic loads, and

Table 4
Participants' computer experience (average given for "frequency of use," number of yes's given for Yes/No questions).

Team	Rank	Type of computer used?[1]	Frequency of use?[2]	Taken a computer course?	Used a mouse or trackball?	Programmed for yourself?	Programmed for some one else?	Own a computer?
UA01	LTC	WS	1	No	No	No	No	No
	MAJ	WS	1	Yes	Yes	Yes	Yes	Yes
		PC	1					
UB04	COL	M	5	No	No	No	No	Yes
		PC	5					
	LTC	WS	5	No	Yes	Yes	Yes	Yes
		PC	5					
UB09	MAJ	PC	5	No	Yes	Yes	No	Yes
	CPT	PC	5	No	Yes	No	No	Yes
UA11	MAJ	PC	3	Yes	Yes	Yes	No	Yes
	MAJ	-	-	No	Yes	No	No	Yes
			2.5	2	6	4	2	7
SA03	MAJ	M	5	Yes	Yes	No	No	No
		WS	2					
	MAJ	WS	1	No	Yes	Yes	No	Yes
SB06	MAJ	PC	5	No	No	No	No	Yes
	MAJ	PC	4	No	No	No	No	No
		WS	1					
SA08	MAJ	-	-	No	Yes	No	No	Yes
	MAJ	-	-	No	No	No	No	Yes
SB12	MAJ	-	-	No	No	No	No	No
	MAJ	PC	3	Yes	Yes	Yes	No	Yes
SA13	MAJ	PC	5	No	Yes	Yes	No	Yes
	MAJ	WS	3	No	No	No	No	No
			2.3	2	5	3	0	6
CB02	LTC	WS	5	Yes	Yes	Yes	Yes	Yes
		PC	4					
	LTC	WS	5	Yes	Yes	Yes	Yes	Yes
		PC	4					
CA05	MAJ	PC	5	Yes	Yes	Yes	Yes	Yes
	MAJ	PC	5	Yes	Yes	Yes	Yes	Yes
CA07	MAJ	PC	5	Yes	Yes	Yes	Yes	Yes
		WS	3					
	MAJ	PC	4	No	No	No	No	Yes
CB10	MAJ	PC	5	Yes	Yes	Yes	No	Yes
		WS	1					
	MAJ	PC	4	Yes	Yes	No	No	Yes
CB14	MAJ	PC	4	Yes	Yes	Yes	No	Yes
	MAJ	PC	3	No	No	No	No	Yes
			4.5	8	8	7	5	10

[1] M - Minicomputers/mainframes (DEC, VAX, IBM, CDC, etc.)
WS - Workstation (Sun, Apollo, IBMRT, MASSCOMP, Symbolics, etc.)
PC - Personal computers (IBM, MacIntosh, Apple, etc.)

[2] 1 - Less than monthly
2 - Monthly
3 - Weekly
4 - Every few days
5 - Daily

Table 5
Number of teams identifying facts that matched the experts

METT-T	Unspecif.	Structured	Computer	Facts Identified by the Experts
Mission	0	4	4	16 Mech Inf Div to seize Obj Alpha.
	2	0	0	Corps main attack by 32 AD to the South.
	0	0	0	Division zone narrowed to better apply combat power.
Enemy	0	3	3	15 MRD at 60-65%.
	2	2	1	33 GTD positioned as 2nd echelon force of 10 CAA.
	1	2	2	Enemy employing hasty defense.
	0	2	2	Enemy 2nd echelon (18 MTR) blocks Northern avenue.
	3	1	0	Enemy 1st echelon dispositions within sector are stronger in the South.
	1	0	0	Enemy Central Front is a secondary effort, enemy main effort in North.
Terrain and Weather	3	1	1	Lines of communications are good in the North, fair in the South.
	0	2	2	Fulda river is generally unfordable in the North, fair in the South.
	3	0	1	1.2 inches of rain on 1-2 September, possible affect on fordability.
	2	0	1	Rhine river is fordable.
	0	2	1	Large scale movement of vehicles is restricted by forests and built-up areas.
	1	0	0	Terrain is restricted in the North.
	0	0	0	Poor cross country movement of tracked vehicles.
Own Troops	1	2	5	Div is at 86% pers strength, 88% major equipment (3 bn of 3d Bde are low, 1 bn of 1st Bde is).
	0	2	2	Corps slice available: FA Bde, AH Bn, Engr (C) Bn, Engr Brg Co, Cml (Smoke) Co.
	1	0	0	Only two bridge companies are available.
	0	0	0	Ammunition: required load equals basic load.
	0	0	0	POL: required load equals basic load.
	0	0	0	26 MID to the North begins attacks on 051200 Sep to seize IGB objectives.
Time	1	3	3	Attack begins at 051200 Sep.
	0	0	1	It is now 042400 Sep.
	5.2	5.2	5.6	Average number of facts recognized (total of 24 identified by expert panel).

adjacent unit attack time) were important but not neccessarily critical to planning success.

Five of the expert-identified facts were not indicated by any of the participants. The facts identified by the most teams were attack mission of the division, strength of the opposing enemy division, strength of own division, and start time for the attack. These facts were explicitly referred to by an average of 7 of the 14 teams.

Three of the four teams selecting the Northern COA had recognized one or two of the facts related to the difficulties with the Northern COA (shown in bold type in Table 5). Team SA13 identified the Fulda as unfordable and team UA01 identified the Haune as fordable (though both teams later only referred to the requirement for a river crossing in their COA justification). Team CB10 identified both facts. None of the four teams selecting the Northern COA (contrasting the experts' choice of the Southern COA) recognized that the enemy 2nd echelon blocked the Northern avenue or the limitations in bridging assets.

List Assumptions (Step 3)

All teams were given a set of assumptions developed by the expert panel to help bound excursions they might be tempted to take. No performance measures were collected in relation to this step.

Array the Forces (Step 4)

The structured and computer-supported teams had to task organize friendly and enemy forces for the main attack, the supporting attack, and reserve. The difference in allocation of combat power relative to the expert panel was calculated and results are presented in Table 6. One of the computer-supported teams failed to complete the arraying of forces partly because of equipment problems. The unspecified teams were not explicitly required to array the forces, but their written materials, notes, and video tapes were inspected to determine if the step was performed. Two unspecified teams arrayed the forces and one of these also calculated combat power ratios. The two teams that arrayed forces chose the non-preferred COA while the two teams who failed to array forces chose the COA preferred by the expert panel.

Positive values in Table 6 for main and supporting attack indicate that not all combat power was used. Negative values for reserves indicate that a higher amount of the available combat power was left in reserve. Inspection of the Table reveals that both structured and computer-supported teams allocated noticeably less combat to the main attack than did the expert panel. The expert panel used a combat power of 26.5 in the main attack (see Figure 5). The differences from the expert panel in combat power arrayed are shown in Figure 6. The structured and computer-supported teams provided 26 and 45 percent less combat power to the main attack, respectively, than did the

Table 6
Mean of combat power differences from the expert panel for unspecified, structured, and computer-supported teams

Condition	Statistic	Main Attack	Supporting Attack	Reserves	Array Deficit	Total Array Error
Unspecified	Observed (n=1)	8.9	0.5	1.3	10.7	10.7
Structured	Mean (n=5)	6.8	0.5	-1.7	5.6	12.0
	Std Dev.	6.4	1.9	4.6	8.2	8.8
Computer-supported	Mean (n=4)	11.8	1.0	-0.7	13.5	18.2
	Std Dev.	4.8	3.3	4.9	11.9	8.2
Combined	Mean (n=10)	9.0	0.7	-1.0	9.3	14.3

experts. There was no significant difference between the structured and computer-supported teams in how they arrayed combat power for the main attack (t test statistic=1.29, α=.26).

The array deficit score shown in Table 6 indicates that the teams failed to allocate all their assets. The total combat power for the friendly forces was 44.9, so the structured and computer-supported teams failed to allocate 12 and 30 percent of the available combat power, respectively. The team following unspecified procedures failed to allocate 24 percent of the available combat power. Three of the ten teams allocated all of their combat power assets.

The total array error represents the absolute difference score for the main attack, supporting attack, plus the reserves. Inspection of the data from individual teams indicates that a large portion of the total array error is due to failure to allocate sufficient combat power to the main attack. There was no significant difference (t test statistic = 1.08, α=.33) between the structured and computer-supported teams in their total array error.

Critical Events (Step 5)

The expert solutions for COA N and COA S contained four and five critical events, respectively. Each COA also had one critical event for the supporting attack. The experts' supporting attacks consisted of a single critical event (fixing the enemy) for both COAs because of the lack of strength of friendly forces combined with enemy disposition and environmental considerations.

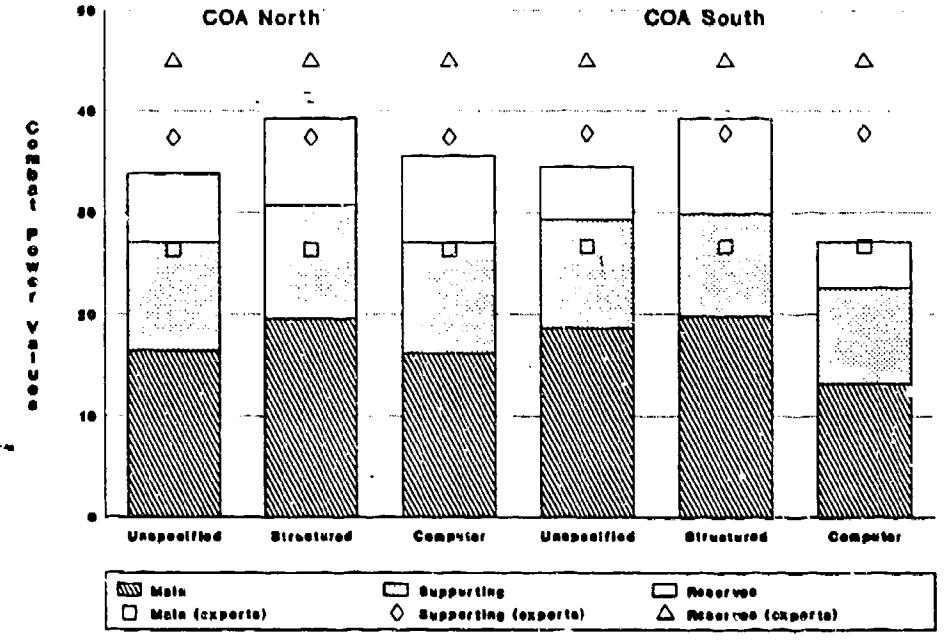

Figure 5. Average combat power arrayed.

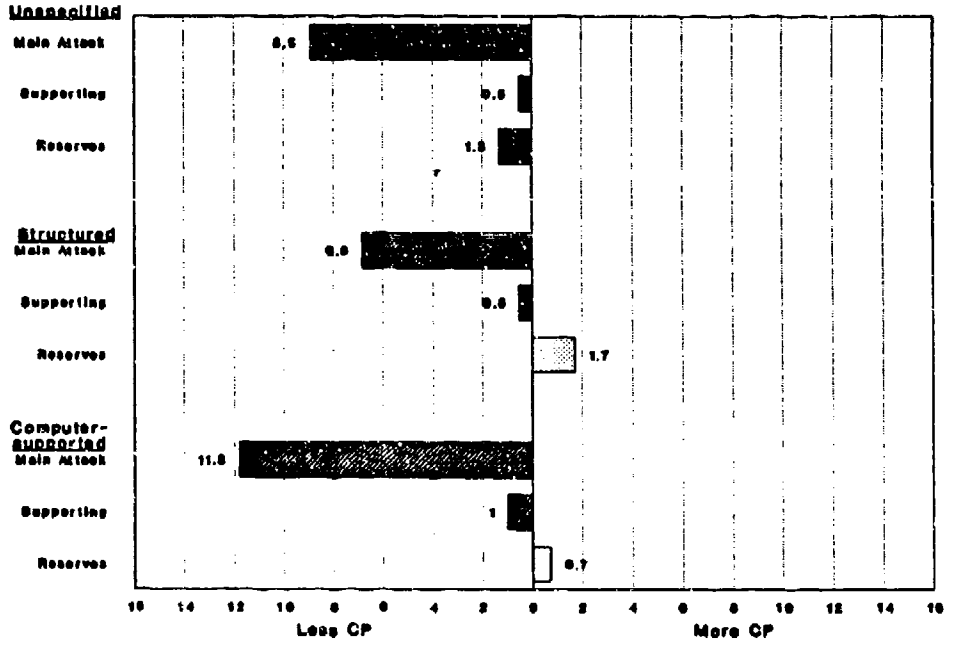

Figure 6. Average difference from combat power (CP) arrayed by experts.

Table 7
Critical events correctly identified and additional ones not judged critical by the expert panel

	Critical Events	Unspecified (n=1)	Structured (n=5)	Computer-supported (n=4)
COA North	Penetrate enemy 1st echelon	0	3	2
	Cross Fulda River	1	4	4
	Cross Haune River	0	4	2
	Seize objective	1	4	4
	Fix enemy in supporting attack	0	5	3
	Average correct matches		4.0	3.8
	Number additional critical events	3	5	5
COA South	Penetrate enemy 1st echelon	0	1	2
	Defeat 18 MTR	0	5	3
	Cross Fulda River	1	4	2
	Cross Haune River	0	2	1
	Seize objective	1	4	4
	Fix enemy in supporting attack	0	5	3
	Average correct matches		4.2	3.8
	Number additional critical events	3	9	9
	Percentage of matches	36%	75%	69%

Critical events were identified by the structured and computer-supported teams for the main and supporting attacks for both COAs. One of the four unspecified teams also identified critical events. A correctly identified critical event required a match to the expert panel's location and description. One computer-supported team did not array forces.

The structured and computer-supported groups identified nearly the same number of critical events and both group identified the majority of events identified by the expert panel. Table 7 identifies the number of teams in each condition matching the experts' critical events, the average number of correct critical events for teams and each COA, and the number of extra critical events. When data were summarized across COAs and types of attack (main and supporting), the structured and computer-supported groups identified 75 and 69 percent, respectively, of the critical events identified by the expert panel. Five of ten teams identified at least 80 percent of the critical events identified by

Table 8
Averages, standard deviations (in parentheses), and sample size (n=) of raw scores for three objective war gaming factors

Objective Factors	COA	Experts	Structured	Computer-Supported
Friendly Equipment Losses	North	341	130 (75) n=5	104 (73) n=3
	South	327	147 (53) n=5	134 (110) n=3
Enemy Equipment Losses	North	219	340 (197) n=3	176 (157) n=3
	South	214	371 (181) n=3	259 (260) n=3
Battle Duration (hours)	North	47	35 (19) n=5	32 (14) n=2
	South	33	37 (19) n=5	32 (14) n=2

the expert panel. All teams identifying critical events identified more than the expert panel. This trend was more pronounced with the supporting attack. For the supporting attack, direct observation of performance suggested that teams believed they could continue the supporting attack past the first critical event. The expert panel considered this unfeasible.

The unspecified teams were not required to identify critical events, though one team did (UA01). This team identified two matching critical events on each COA and three critical events which the expert panel did not recognize as critical. This team also selected the Northern COA.

War Gaming Critical Events (Step 6)

It was up to the individual teams to decide which of the eight objective factors they would use to estimate war gaming results. At their own choosing, teams could also provide separate predictions for the three phases of a critical event (preparatory, during, consolidation) or a single prediction for each critical event.

Table 8 presents the war gaming results for the three objective factors used by the expert panel. Figure 7 shows the differences of number of equipment losses and battle duration among the computer-supported and structured, manual groups and the expert

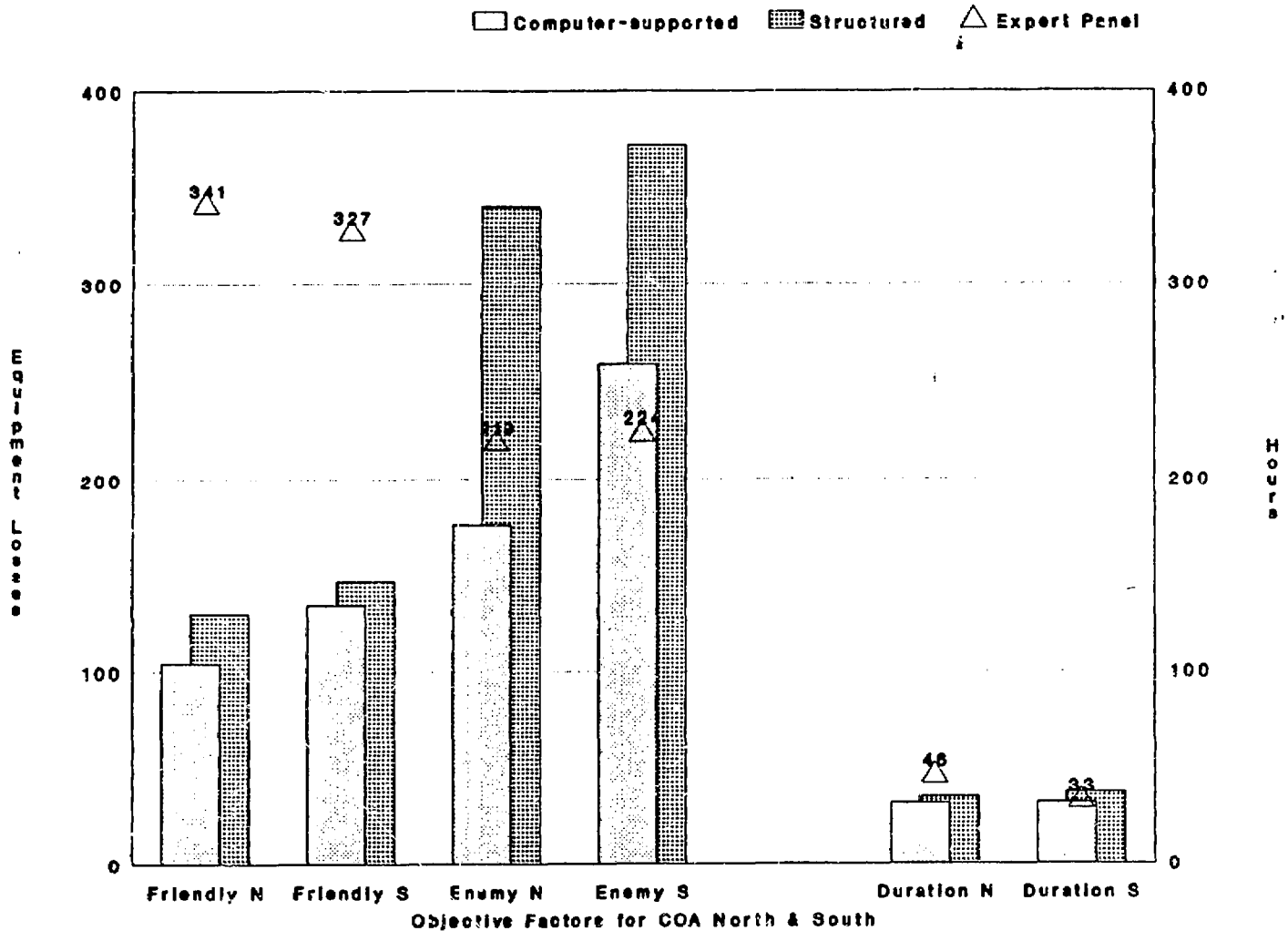

Figure 7. Average objective battle assessments.

panel. Variability in the raw data was high for all three measures. Examination of data from structured and computer-supported teams indicated the projections of more friendly equipment losses for COA S in seven of eight teams; therefore, projections favored COA N for this factor. These predictions were contrary to the expert panel who projected more losses for COA N (COA N = 341; COA S = 327). On the average both sets of teams under-estimated the friendly equipment losses compared to the expert panel. For enemy equipment losses, the predictions of all seven teams from both groups favored COA S as did the predictions of the expert panel. The structured teams over-estimated the enemy equipment losses compared to the expert panel. The computer-supported teams were closer to the expert panel estimates on this factor.

As indicated, the predictions of the expert panel for the two equipment loss measures favored one COA over the other by only a marginal amount. By contrast, the experts' prediction for battle duration was more definitive; the values were 47 and 33 hours for COA N and COA S, respectively. Most teams' predictions did not agree with the expert panel's preference for COA S. The duration predictions of six teams favored COA N while three teams favored COA S. One team had equal battle durations for the COAs.

Scale and Aggregate Battle Results (Step 7)

Once estimates had been made for the objective factors on each critical event, the teams scaled the objective factor scores using a 9 point scale, to allow weighting, addition, and comparison. A low scale value ("1") means a low utility or benefit value. Figure 8 shows pairs of scaled scores for COA N and COA S for each team. The top diagram (Figure 8a) shows the comparison of scaled scores for friendly equipment losses. The expert panel is shown in the middle with no advantage for either COA. Three teams had an advantage going to COA N, another team had the advantage to COA S, and four teams had no difference.

For Enemy Equipment losses the middle diagram (Figure 8b) shows again that the expert panel gave no advantage to either COA. Three teams had an advantage going to COA S. Three other teams showed no difference in scaled values.

For Battle Duration (Figure 8c) the expert panel gave the advantage to COA S, by two scale values. One team from each of the two experimental conditions agreed with the advantage to COA S. Four teams gave the advantage to COA N for battle duration and three teams using this objective factor had no difference in scaled values.

Comparison of COA (Step 8)

The first step in the comparison was to assess the COAs on subjective factors. Each structured and computer-supported team had the option of selecting from a set of four subjective factors which were provided on the work sheets or to add factors of their

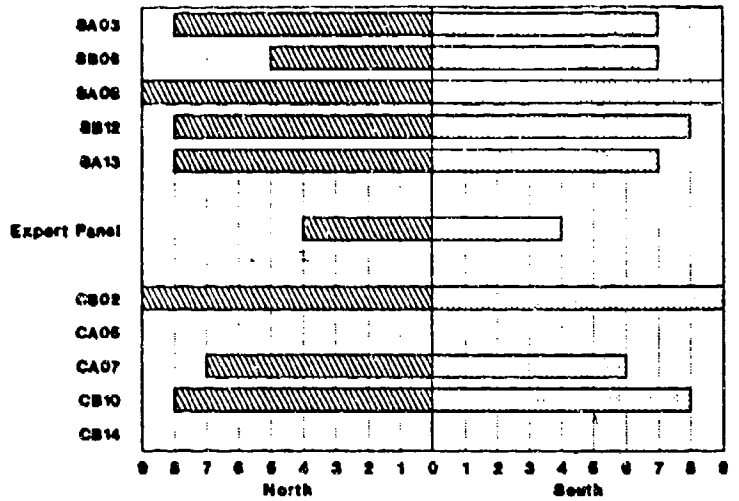

Figure 8a. Friendly equipment loss.

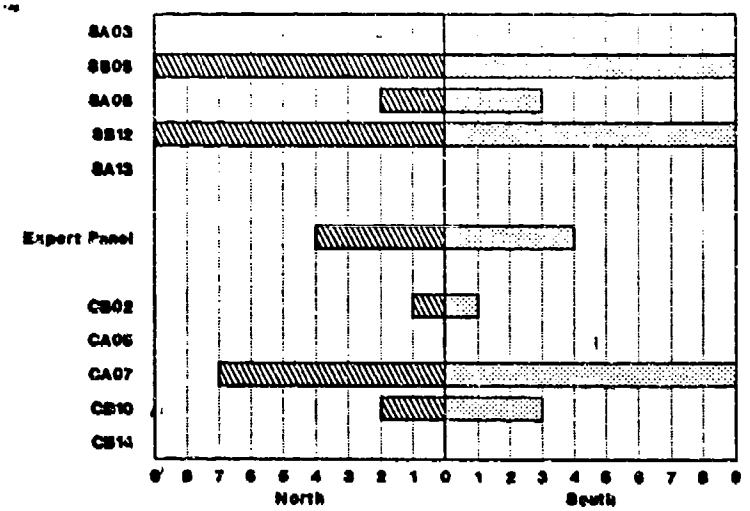

Figure 8b. Enemy equipment loss.

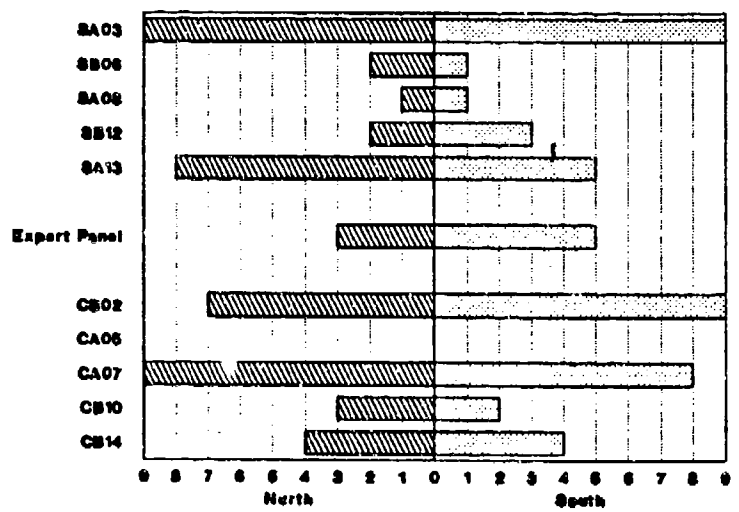

Figure 8c. Battle duration.

Figure 8. Scaled battle result scores for COA N and S.

own. Teams also assigned a scale value from 1 to 9 for subjective factors. A team then weighted the individual objective and subjective factors in preparation for aggregation and comparison of the COAs. Based on the aggregation procedures, the COA with the higher score was the preferred COA. The expert panel had scores that favored COA S for both objective and subjective factors. Table 9 shows the raw data for each structured and computer-supported team and the expert panel.

Aggregate scores for subjective factors for the two COAs were noticeably different. COA S was favored by eight teams and COA N was favored by two teams. Aggregate scores for subjective factors indicated the COA that was eventually chosen by all ten teams. The eight teams with higher subjective scores for COA S chose COA S while the two teams with higher scores for COA N chose that COA.

Not all objective and subjective factors were considered by all teams. Table 10 summarizes the number of teams that considered a particular measure and the average weighting assigned to that measure when it was considered. Note that the three factors given the highest weighting by the participants teams were some of the highest weighted factors for the expert panel. Two subjective factors (flexibility and risk) that were weighted high by the experts were not rated as high by the participants. Examination of the data indicates considerable inter-team variability for both of these factors that are very difficult to predict, particularly risk.

In order to inspect the weighted sums, a percentage difference was computed for each teams' pair of weighted sums. The difference between objective scores for COA S and COA N were divided by each team's combined weighted sum on the higher COA. A similar percentage was calculated by taking the difference of the subjective COA S score from the COA N score and dividing by the total weighted sum of the higher. Figure 9 shows the results. The darker shading shows the proportion of the difference contributed by the objective factor, and the lighter shading shows the subjective proportion. This figure clearly shows the predominance of the subjective factors in distinguishing between the COAs. Three teams (SA03, SB12, and CA07) had objective factor results which supported COA N but a greater proportion of their subjective factor supporting COA S. The figure shows two of the teams (SA13 and CB10) who chose the non-expert selected COA. Comparing the length of the bars in the figure to the expert panel value also shows that several teams selecting the expert-selected COA over-estimated the advantage in COA S by a factor of two (in the case of CB02) and of three (in the case of SB06).

COA comparison errors. The critical event war gaming and COA summary comparison sheets of the structured teams were checked for arithmetic errors. COAAT automatically performed arithmetic operations for the computer-supported teams. Four of the five structured teams made addition or multiplication errors. Team SA08 made no calculation errors. Team SA03 added columns incorrectly on the critical event war gaming sheet. For POL expended on COA S they totalled 20% instead of 25%. For ammunition on COA S they had 50%, instead of the 40% they would have had if their base figures had been added correctly. Team SB06 added duration of the supporting

Table 9
Objective and subjective factor war gaming results by team, COA, and factors

Team	COA	Fr Pers	Fr Eqmt	En Pers	En Eqmt	POL	Ammo	FEBA Mvmt	Time	Obj Total	Man Accpl	Asset Use	Flex-ible	Fut. Opns	Risk	Other	Subj Total	Total
CB02	N	540	540	70	70	60	10	720	700	2710	500	90		300	210		1100	3810
	S	540	540	70	70	70	20	720	900	2930	500	810		360	490		2160	5090
CA07	N	42	70	56	63	28	30	45	81	415	9	14	5	5	21	21	75	490
	S	42	60	72	81	20	6	45	72	398	27	14	15	10	21	21	108	506
CA05	N	350		225				720	630	1925	600			420	400	540	1960	3885
	S	350		300				720	630	2000	800			420	400	720	2340	4340
CB14	N										90	15	20	30	12	49	216	216
	S										90	12	25	20	18	101	266	266
CB10	N	855	760	50	100				300	2065	900		630	630	100		2260	4325
	S	855	760	100	150				200	2065	900		360	360	60		1680	3745
Expert Panel	N		400		240				240	880	500	360	320	280	400		1860	2740
	S		400		240				400	1040	800	480	560	240	640		2720	3760
SA08	N	900	675	225	150				50	2000	900	800	360	525			2585	4585
	S	900	675	225	225				50	2075	900	900	360	525			2685	4760
SA03	N	640	640							1280	800		240	630	300		1970	3250
	S	640	560							1200	800		360	630	480		2270	3470
SB06	N		400		450				200	1050			240	200			440	1490
	S		560		450				100	1110			560	700			1260	2370
SB12	N	140	560	630	630	240	180		180	2560	500		180		60		740	3300
	S	140	560	630	630	240	60		270	2530	700		300		180		1180	3710
SA13	N	8	8						24	40	14		5	16	7		42	82
	S	8	7						15	30	10		7	10	5		32	62

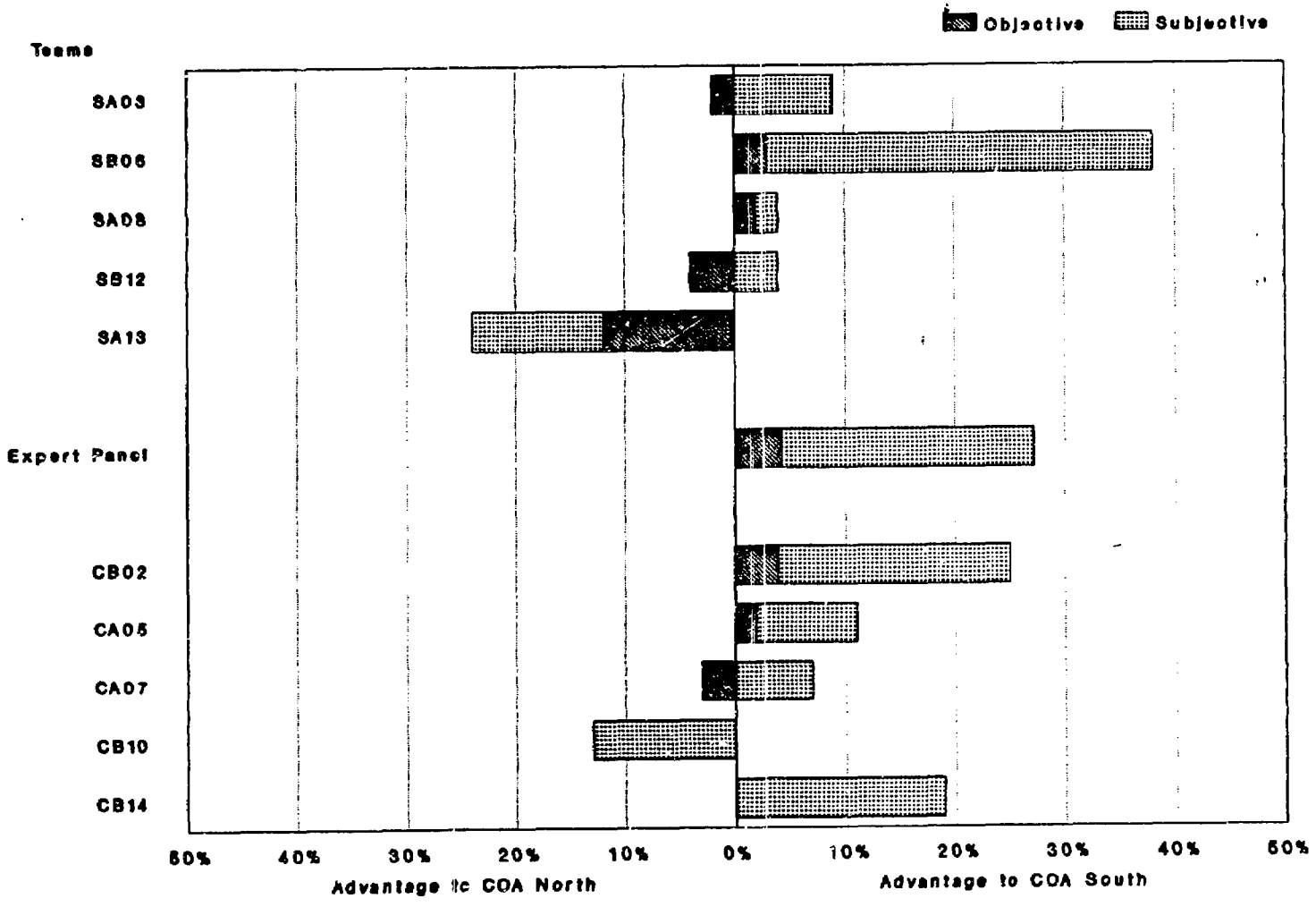

Figure 9. COA S - COA N difference relative to total score of preferred COA

Table 10
Relative weights for objective and subjective factors for teams and the expert panel

Factor type	Factor	Number of teams	Average weight	Experts' weight
Subjective	Mission accomplishment	9	95	100
Objective	Battle duration	8	90	80
Objective	Friendly equipment losses	8	74	100
Subjective	Effective use of assets	4	73	60
Subjective	Facilitate future opns	9	71	40
Objective	Enemy personnel losses	6	70	na[1]
Objective	FEBA movement	3	70	na[1]
Objective	Friendly personnel losses	8	69	na[1]
Objective	Enemy equipment losses	6	68	60
Subjective	Flexibility	8	60	80
Subjective	Risk	8	53	80
Objective	Ammunition expended	3	33	na[1,2]
Objective	POL expended	3	27	na[1,2]

[1] Not weighted by the expert panel.
[2] Estimates indicated POL and ammunition were not a problem.

attack to the duration of the main attack. Since the events occur simultaneously, time should not be added. They had 62 hours for the duration of COA S; instead their figures should have added to 57 hours. Team SA13 also made an error in battle duration addition. Their figures summed to 24 hours for COA N; instead it should have been 26 hours. Team SB12 made a multiplication error on their COA summary work sheet. A weighted scaled score for ammunition expended on COA N should have been 33.0, but through error in multiplication they had 34.8.

Confidence in war game estimates. In the questionnaire phase after the experimental tasks, participants from the structured and computer-supported teams were asked to rate the confidence they had in their war game estimates. Figure 10 shows the average confidence ratings by objective factors and teams. Participants gave an average rating of 2 ("not very confident") on a 5 point scale over all eight objective war game factors. Computer-supported teams rated their confidence of enemy equipment estimates lowest and movement of FEBA highest. Structured teams rated enemy personnel loss estimates lowest and Class III (POL) highest. Only once was an

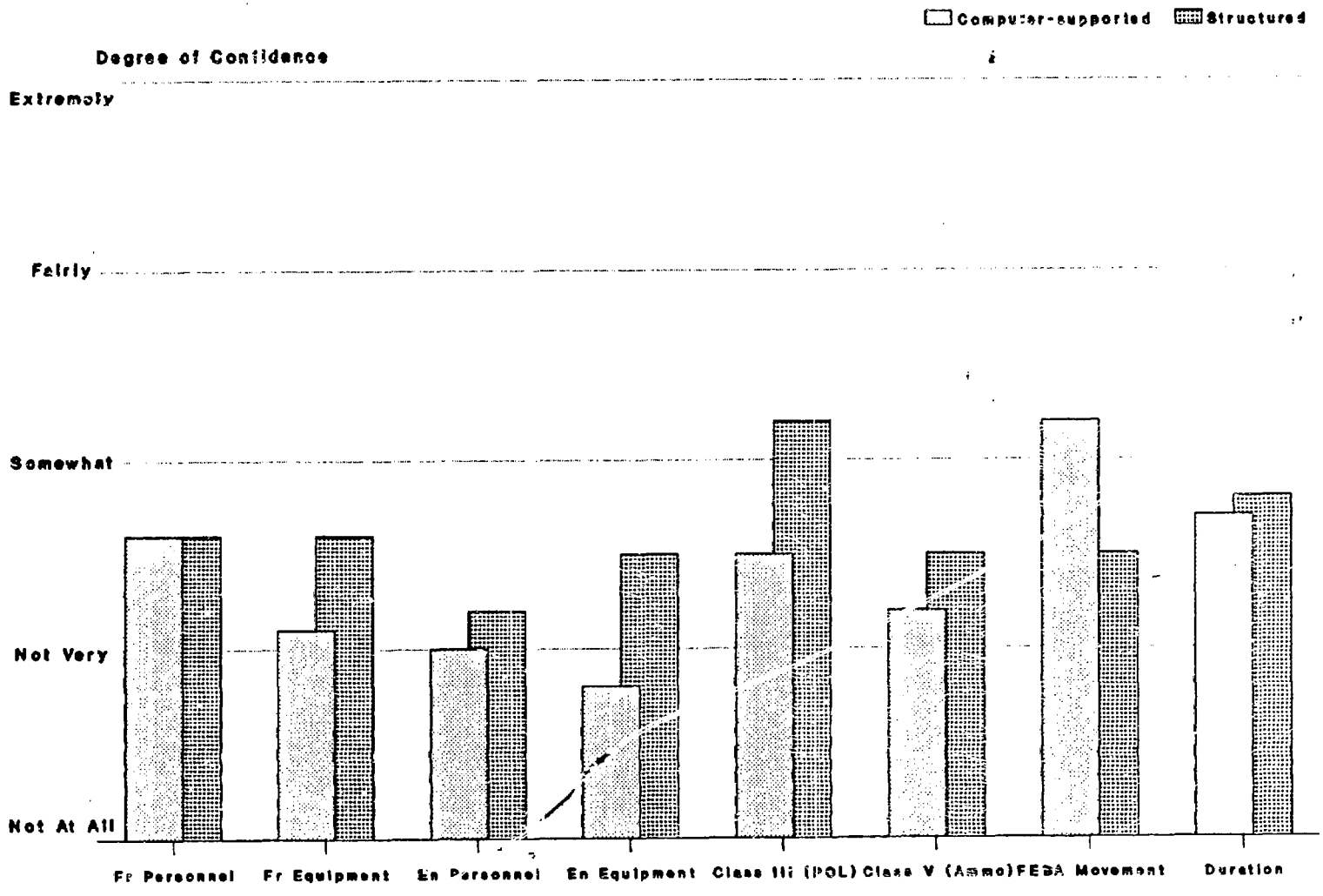

Figure 10. Teams' confidence that estimates support accurate war gaming

"extremely confident" (5) rating made for any of the factors, while 19 percent of the individual ratings were "not at all confident" (1).

The average of the team's confidence ratings was correlated with the absolute value of the difference between the expert's estimates (averaged over COA N and S) and the team's estimates for three war gaming factors (friendly equipment loss, enemy equipment loss, and duration. A low negative correlation (Spearman's correlation = -.1429, $\alpha = .75$) was obtained for friendly equipment loss error and confidence. (Note: the participants had no feedback from the experts' estimates to use in judging confidence.) There was a similar relationship between the error in duration estimates and a team's confidence in that estimate (Spearman's correlation = -.2758, $\alpha = .45$).

Teams which made greater errors had higher levels of confidence in their enemy equipment loss projections (Spearman's correlation = .5268, $\alpha = .24$). If direction of the error is considered (absolute value not taken) then a reversal in the correlation occurred. Teams which estimated more enemy losses than the experts were more confident, than those which had lower loss estimates than the experts (Spearman's correlation = -.7946, $\alpha = .03$) (see Figure 11).

COA Decision and Justification (Step 9)

COA Selection. The expert panel preferred COA S. This COA was preferred by two of four teams in the unspecified condition and four of five teams for both the structured and computer-supported conditions.

Multi-attribute utility comparison to experts. Table 11 shows the teams who considered justification factors that were used by the expert panel. When teams considered a factor, they usually considered it in the same context as the expert panel. One exception to this finding was that battle duration was incorrectly assessed as favoring COA N by eight of 14 teams.

Teams choosing the preferred COA had a mean score of 67 percent (see section 2.5 for scoring rules), while teams choosing COA N had a mean score of 46 percent.

Merit of justification. Table 12 illustrates the scoring logic and the resulting scores for each team. Ties in the point totals among teams were broken by assessment of the quality of their justifications and whether they recognized the importance of the opposed river crossing. Table 13 provides an explanation of the relative quality of each team's justification ranking.

The rank orders of the scores were significantly different showing a significant treatment effect (Kruskall-Wallis test statistic = 5.99, $\alpha = .05$). Both the computer-supported and structured groups performed better than the unspecified group (Mann-Whitney test, $\alpha = .05$). There was not a difference between the computer-supported and structured groups (Mann-Whitney test, $\alpha > .05$).

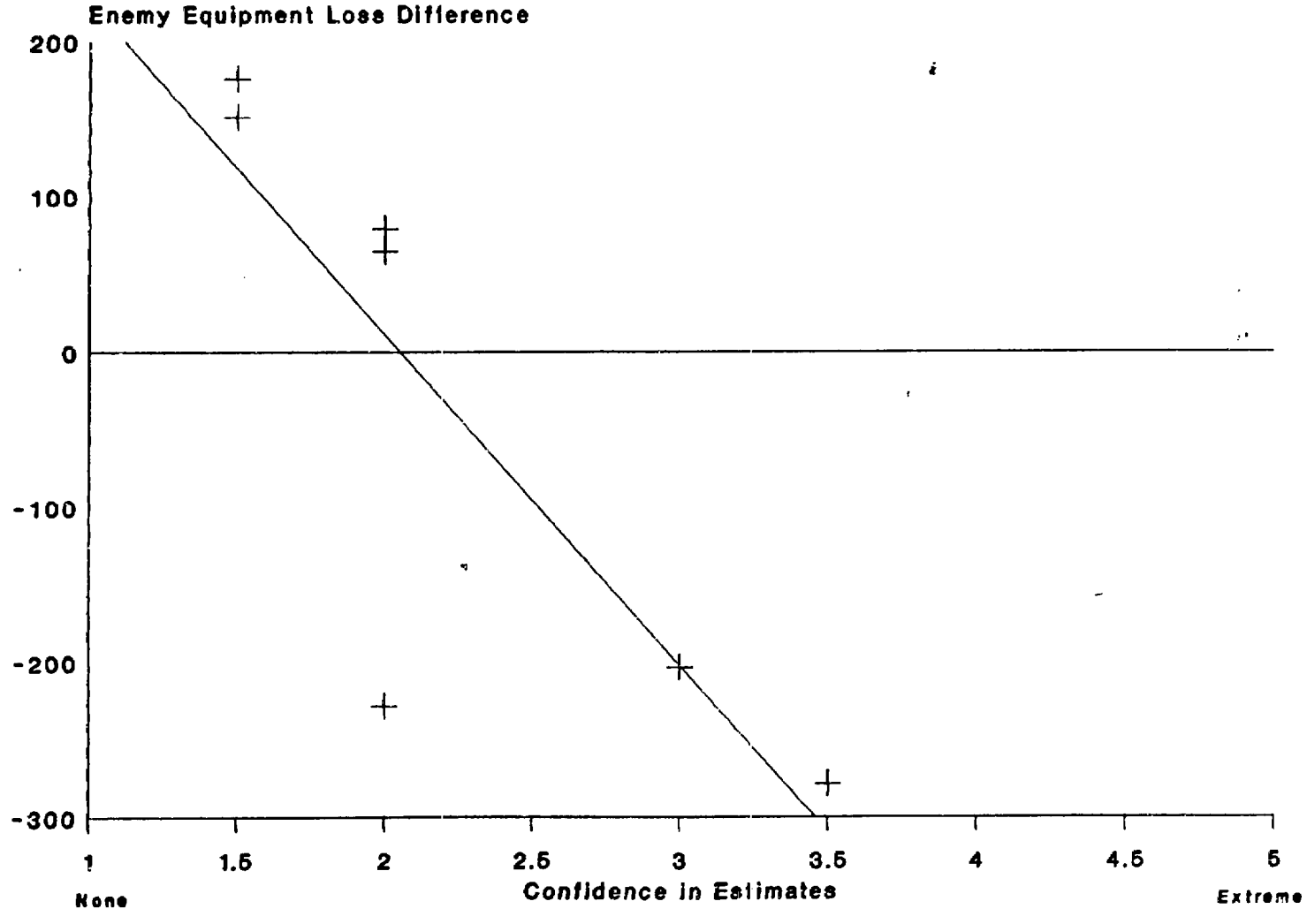

Figure 11. Relationship of confidence and enemy equipment loss projection.

Table 11
Teams correctly (✓) and incorrectly (-) identifying expert panel justification factors (an empty cell indicates the factor was not mentioned in a team's justification).

	Expert Panel	Unspecified Teams					Structured Teams						Computer-supported Teams					
METT-T	Justification Factors	1	4	9	11	Total	3	6	8	12	13	Total	2	5	7	10	14	Total
Mission	Accomplish the mission					0						0				✓		1
Enemy	Enemy 1st echelon force strength	✓		✓		2	✓		✓	✓	✓	4	✓	✓		✓	✓	4
	Encounter enemy 2nd echelon force				✓	1	✓	✓	✓			3	✓	✓	✓			3
	Enemy equipment losses					0						0		✓				1
Terrain	Avenue of approach restrictions	-	✓	✓	✓	3	-		-	✓	-	1		✓	✓		✓	3
	Major river obstacles					0			✓	✓		2	✓	✓	✓	✓		4
	Major city obstacles	✓	✓		✓	3				✓		1	✓	✓		✓		3
	Lines of communication	✓		✓	✓	3			✓			1		✓	✓		✓	3
	Distance to objectives					0						0	✓					1
Own Troops	Engineer bridging requirements					0			✓			1	✓		✓		✓	3
	River crossing operation	✓			✓	2	✓	✓	✓	✓	✓	5	✓	✓	✓			3
	Protected flank(s)		✓			1						0			-	✓		1
	Force repositioning requirements for attack					0		✓		✓		2						0
	Major equipment losses			✓	✓	2		✓				1		✓		-		1
Time	Battle duration	-	✓	-	-	1	-	-		✓	-	1	✓	✓	✓	-	-	3
Totals		4	4	4	6	24	3	4	6	7	2	22	8	10	7	5	4	34

Table 12
Ranking of teams' solution justifications with points awarded for enemy/mission and terrain/asset considerations

Ranking	Team	Total Points	COA	Enemy/Mission Considerations	Points	Terrain/Assets Considerations	Points
1	CB02	7	S	2nd echelon defends North at Fulda river.	4	Bridging assets are limited.	3
2	CA07	7	S		4		3
3	SA08	7	S		4		3
4	CA05	6	S		4	Fulda is fordable in South.	2
5	SA03	5	S		4	River crossing is required.	1
6	SB06	5	S		4		1
7	SB12	4	S	2nd echelon identified. Error in type of engagement (-2).	2	Fulda is unfordable in North.	2
8	UA11	3	S	2nd echelon identified. Error in location of engagement (-2).	2	River crossing is required.	1
9	CB14	3	S	No reference to 2nd echelon.	0	Bridging assets are limited.	3
10	CB10	2	N		0	Fulda is unfordable.	2
11	SA13	1	N		0	River crossing is required.	1
12	UA01	1	N		0		1
13	UB04	0	S		0	No reference to river obstacle.	0
14	UB09	0	N		0		0

Table 13
Factors used in scoring and ranking team COA selection and justifications.

Rank	Team	COA	Factors*	Points
1	CB02	South	• opposed river crossing	+4
			• only 2 bridge companies	+3
			• desire to defeat 18th MTR in other than defensive positions	
2	CA07	South	• 18 TR in prepared defensive positions	+4
			• limited engineering and bridges	+3
			• key terrain on OBJ, speed, air attacks	
3	SA08	South	• dug-in MTR in 2nd echelon	+4
			• limited bridge assets	+3
			• defeat 15 MRD 2nd echelon with attack helicopters vs. headlong engagement	
4	CA05	South	• opposed river crossing	+4
			• fordable rivers in South	+2
			• COA N has more time risk, better chance of mission success in South	
5	SA03	South	• 2nd echelon in prepared defense	+4
			• river crossing	+1
			• greater flexibility, less risk	
6	SB06	South	• frontal attack into enemy	+4
			• river crossing	+1
			• least movement, positioning of units	
7	SB12	South	• Bridge Fulda (fordability not limited assets)	+2
			• enemy counterattack at Haune, [possible head-on mtg engag. w/reserve]	+2
			• shortest time, greater flexibility	
			• does not allow enemy to prepare defenses	
			• if support attack fails, subject to flank counterattack	
8	UA11	South	• 15th MRD reserve defends forward of Fulda	+2
			• Fulda fordable in South	+2
			• [bridging an advantage, crossing by bridging in South]	
			• [fastest avenue to objective in North, main attack avoids enemy strength]	
9	CB14	South	• constrained by bridges	+3
			• more flexible	
			• [faster reaching objective]	
10	CB10	North	• river crossing, unfordable river	+2
			• [bridge assets allow crossing]	
			• [defeat counterattack disadvantage in South]	
			• [North faster]	
11	SA13	North	• river crossing	+1
			• [may encounter elements of 18 TR, once crossed and defeated rapid advance]	
			• [counterattack by 18 TR slows South, North is faster]	
12	UA01	North	• river crossing	+1
			• [rivers not fordable after 7 Sep]	
			• approach to rivers favor enemy in defense	
			• [time advantage in North]	
13	UB04	North	• none	
			• speed advantage in South	
14	UB09	North	• none	
			• [terrain more advantageous to rapid movement]	
			• [speed]	

*Errors are placed in brackets ([]). Errors and quality of factors were used for breaking ties in rank order.

Performance Times

Although times were not completely free to vary, measures of time were analyzed to determine any differences among experimental conditions and relationships to other variables. The total time to complete all the tasks was regulated through instructions. All teams were given a completion time. Additional time was granted when teams needed it. Structured and computer-supported teams were also given completion times for each step. The experimenter reminded participants to keep within time requirements when they appeared to be taking too long. Teams were allowed to complete tasks faster than the allowable time for each step and were allowed to go on to the next step if they desired.

Figure 12 shows the cumulative average times (plus and minus one standard deviation) for structured and computer-supported teams. The time guidelines are depicted with an inverted triangle annotated with the specific time. The average final time for the unspecified teams is shown at step 9 as a diamond symbol. The graph shows that the computer-supported teams tended to take longer than either the structured teams or the experimental guidance times for arraying forces and identifying critical events. During these times the computer-supported groups were inputting data into the COAAT decision tool. Their relative unfamiliarity with COAAT (about 30 minutes of training) explains the longer completion times for these steps. There were no significant differences among the experimental groups on the total time to complete the tasks ($F[2,11]=2.57$, $\alpha<.20$). The correlation between the total time and the solution ranking was negative (Spearman's correlation = -.35, $\alpha=.22$) (faster times, poorer solutions), but not significant. Table 14 shows that the critical event step times had a significant negative correlation with solution ranking (faster times, poorer solutions).

Early Decisions. The amount of time used to make a decision was of interest because the estimate process recommends against arriving at premature conclusions; that decisions should not be made until each course of action is independently analyzed and those results compared. A data collection sheet used to profile each team was completed by experiment observers. The observers marked on these sheets when it appeared that a conclusion had been made prior to step 8, compare courses of action. Also participants were asked questions if a conclusion had been made prior to step 8. If one had, they were asked whether that conclusion was the same as the final choice or not and the earliest step in which they made a decision about the course of action.

Figures 13 and 14 show the time before and after the earliest conclusion of either team member for each team. If the teams followed the sequence of steps as directed by the experiment the earliest conclusion would not be reached until after 220 minutes or 85 percent of the time allotted to task performance. Two teams (SA13 and CA05) used a higher percentage of their time before a decision was first reached (94 percent and 86 percent, respectively). Four teams (SB12, SA08, CB02, and CB14) used less than 50 percent (i.e., one standard deviation less than the 85 percent reference point) of their time before they came to a conclusion. There was no significant difference among groups in terms of how early they came to their first conclusion (Kruskall-Wallis statistic

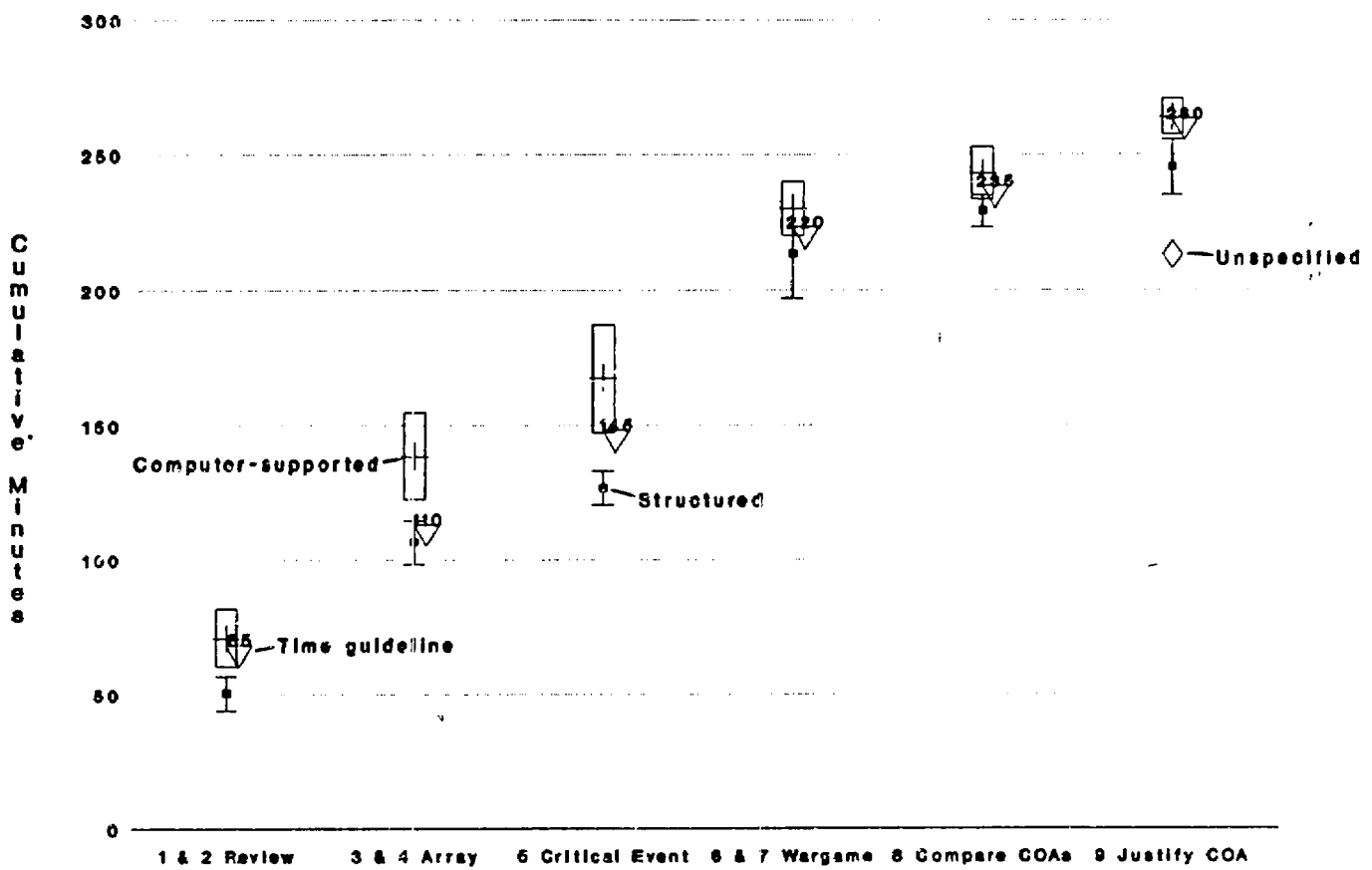

Figure 12. Average cumulative times for task steps and ±1 standard deviation.

Table 14
Correlations between task step times and solution ranking.

Steps	Number of Observations	Spearman Correlation	$\hat{\alpha}$ (2-sided)
2 Gather and review facts	10	-.37	.30
4 Array forces	10	-.38	.29
5 Determine critical events	10	-.63	.05
6 War game critical events	10	.36	.31
7 Aggregate/scale results	10	.14	.77
8 Compare COAs	10	.07	.86
9 Justify COA selection	10	-.20	.59
Average cumulative time for structured and computer-supported	10	-.25	.50
Cumulative time for all teams	14	-.35	.22

= 0.39, $\hat{\alpha}$=.82). Also there was no difference of earliest decision time between those teams selecting COA N and COA S (Kruskall-Wallis statistic = 1.45, $\hat{\alpha}$=.23). There was no significant correlation between a team's justification ranking and the percentage of elapsed time for a decision (Spearman's correlation = .29, $\hat{\alpha}$=.16).

At least one member in each of the ten teams following structured steps came to a conclusion before comparison of COAs (step 8). Also at least one member of five of these teams (SA03, CB02, CA05, CB10, CB14) switched conclusions before their final decision. Four of these five teams switched to the correct COA and one team (CB10) to COA N.

These results indicate that reaching an early conclusion does not impair the ability to make a correct conclusion. Also there did not appear to be any primacy bias; participants changed their mind for the better in 4 out of 5 cases.

Unspecified Teams' Performance

One of the objectives of analyzing unspecified procedures was to see what processes were followed, the variability of those processes, and how they compare to standard processes. The unspecified teams were guided more by the required end state of their assigned task than were the structured and computer-supported teams or than

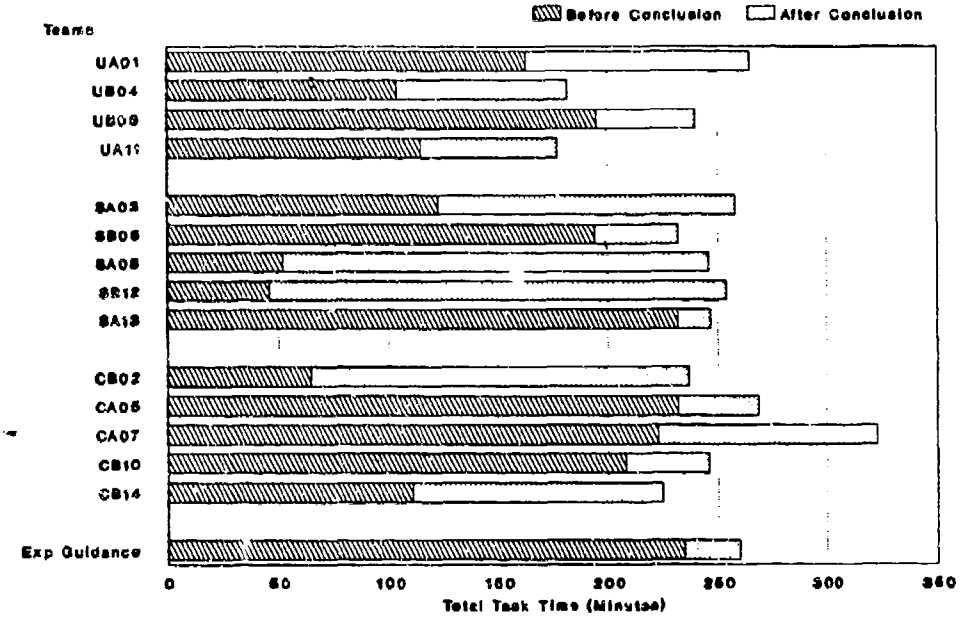

Figure 13. Amount of time before and after earliest conclusion.

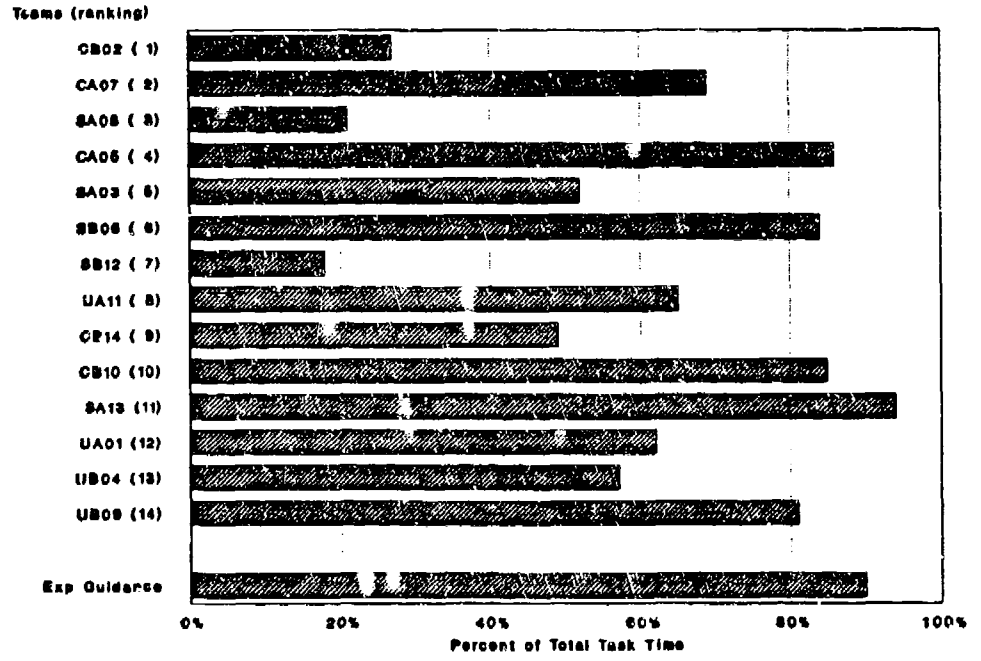

Figure 14. Percent of elapsed time to reach earliest conclusion.

Table 15
Unspecified teams' process sequence

TEAMS			
UA01	UB04	UB09	UA11
Situation assessment	Situation assessment	Situation assessment	Situation assessment
Comparison	Comparison	Array forces (combat power ratios)	Comparison
Concept development pertaining to forces and events	Concept development pertaining to qualitative forces	Situation assessment/ forecasting	Concept development
Visualization of COAs	Comparison	Check completeness against mission goals	Situation assessment (visualization and forecasting)
Check mission goals	Situation assessment	Array forces (combat power ratios)	Comparison
War gaming	Comparison	Comparison	Selection and justification
Comparison matrix	Selection and justification	Concept refinement	
Selection and justification		Array forces (combat power ratios)	
		Comparison	
		Array forces (combat power ratios)	
		Comparison	
		Selection and justification	

they were by standard estimate procedures. But also the unspecified teams appeared to be less certain about how to proceed to arrive at the selection and justification of the COA. Table 15 provides a general summary of the sequence of types of tasks each team performed.

The unspecified teams performed in very different styles and sequences. One of the following explanations applies: (a) participants did not know the process, (b) they did not know how to apply it, (c) they thought they were applying it but weren't, or (d) they did not feel it was appropriate to apply. There was very little in what they did to indicate what was the end of one process step and what began the next. The tasks were done iteratively. The four unspecified teams all did comparisons (strictly qualitative except for UB09) between the COAs at more than one time. Team UB09 repeatedly arrayed forces and calculated combat power ratios. These ratios were only for the force postures and did not

approximate the way the structured and computer-supported teams did their critical event war gaming. With the exception of the team UB09, the unspecified teams performed tasks at a qualitative level, looking for features to discriminate between the COAs. For the most part their searches were done in an unstructured manner viewing the battlefield as a static situation.

The unspecified teams were characterized by frequent references to manuals, suggesting their desire to seek more guidance on the task process. The unspecified teams used an average of 2.25 of four manuals (CGSC ST 100-9, FM 101-5, FM 101-5-1, and FM 101-10-1/2) compared to 1.4 and 1.5 average manuals for the structured and computer-supported teams.

Performance Process Style

Experimenters observed the teams' performance for characteristics of work management, team dynamics, level of knowledge, and performance style. This work was tried to determine if there were any differences on various style dimensions. There were two general reasons that these dimensions were examined: to diagnose differences among the three experimental groups (see Table 16) and differences among poorer and better solution rankings (see Table 17).

Work management. Only 5 of 14 teams made a conscious effort to organize and allocate work. Nine of 14 teams made an observable effort to manage their time, and 4 teams were disciplined in controlling and avoiding distractions. There were no real different trends among the three experimental groups. Six of the 9 teams who deliberately managed time were in the poorer half of solution scores.

Team dynamics. Determining roles was left up to the two participants. The three teams with an unbalanced allocation of work scored in the poorer half. In all cases a leader and subordinate role emerged, but sometimes dominance shifted during the task session. There was a conflict in roles in 2 of the 14 teams. The leader appeared adequate in his role of leading in 10 of 14 cases. Again there were no real differences among the three experimental groups. The teams who scored in the better half with their solution justifications all had adequate leaders, while only three of the seven teams in the poorer half had adequate leaders.

Task and tactical knowledge. Only one of the four (25%) unspecified teams were judged to be adequate in their task and tactical knowledge. In contrast three (60%) computer-supported teams were judged adequate, and four (80%) structured teams were adequate. In 11 of the 14 teams, one member appeared to be noticeably more experienced, knowledgeable, or more motivated than the other.

Performance style. Five teams appeared to be affected by "groupthink", a decision bias where there is unchallenged and unwarranted agreement in an attempt to avoid conflict. Three of these five teams selected the northern COA. Ten of the 14 teams

Table 16

Team Profiles: Frequency of characteristics by experimental group

Characteristics	Unspecified n=4	Structured n=5	Computer-supported n=5
Work management			
Consciously organized work	1	1	3
Followed work allocation	1	1	3
Referred back to plan	0	0	0
Improved on plan	1	0	1
Managed time and sequence of work	4	2	3
Overtly avoided distractions	0	2	2
Team Dynamics			
Balanced team effort	2	4	5
Members shared equal status	0	0	3
Leader/subordinate roles arranged	4	5	5
Subordinate accepted his role	4	4	5
Leader was at least adequate in role	2	5	3
Task and Tactical Knowledge			
Knowledge was adequate	1	4	3
One member dominant in experience, knowledge, or motivation	4	5	2
Performance Style			
Evidence of "groupthink"	2	3	0
Means of reaching consensus - Discussion	3	2	5
Means of resolving conflicts			
Consent to subordinate	0	0	2
Defer to superior	2	3	0
Work performed just adequately	3	4	1
Practiced error checking	2	5	3

Table 17

Team Profiles: Frequency of characteristics by poorer and better solutions*

Characteristics	Poorer Half n=7	Better Half n=7
Work management		
Consciously organized work	2	3
Followed work allocation	2	3
Referred back to plan	0	0
Improved on plan	1	1
Managed time and sequence of work	6	3
Overtly avoided distractions	2	2
Team Dynamics		
Balanced team effort	3	0
Members shared equal status	1	2
Leader/subordinate roles arranged	7	7
Subordinate accepted his role	7	7
Leader was at least adequate in role	3	7
Task and Tactical Knowledge		
Knowledge was adequate	3	5
One member dominant in experience, knowledge, or motivation	5	7
Performance Style		
Evidence of "groupthink"	3	2
Means of reaching consensus - Discussion	5	5
Means of resolving conflicts -		
Consent to subordinate	0	2
Defer to superior	3	2
Work performed just adequately	5	3
Practiced error checking	4	6

*Better half = teams with a solution ranking of 1 through 7. Poorer half = teams with ranks of 8 through 14. (Note that 4 of 7 teams in poorer half selected COA N).

discussed issues to reach a consensus. When conflicts arose, the leader of two of the five computer-supported teams tended to go along with his partner. The subordinate deferred to the leader in five of the nine unspecified and structured teams. Eight of the 14 teams were judged to be performing just adequately (a motivational dimension). Ten of 14 teams performed error checking, six in the better half and four in the poorer half.

Situation Awareness Test

At the end of the performance phase of the exercise all participants were given a 32 item test to check their understanding of the situation. Multiple choice questions were given on the areas of mission, enemy, troops, terrain, and time. The test was developed to be difficult with the rationale that an easy test would not distinguish among individuals. Figure 15 shows that the scores on subsections and the overall test were comparable among the three groups. There were no significant differences among the three conditions (Chi square [8 degrees of freedom] = 0.10, $\alpha > .995$). The average score among participants was 54 percent correct, ranging from 28 to 81 percent. There was no significant correlation between a team's solution justification ranking and the sum of the two individuals' situation awareness test scores (Spearman's correlation = -0.29, $\alpha = .31$).

By considering questions answered correctly and incorrectly, one can infer what information was best acquired and what was not. Table 18 lists the most commonly known and missed questions in the situation awareness test. Question 19 in particular is interesting because it asks where the Fulda river was the most fordable. (The fordability of the Fulda was an important factor in the COA selection.) Seventy-five percent of the participants answered this question correctly. Five of the seven participants answering incorrectly also were on teams scoring in the poorer half of the solution justification ranks. Both members of Teams UB09 and UB04 missed this question, and they also ranked last and second to last (respectively). Team UB09 selected COA N. Both members of each of the three other teams selecting COA N answered this question correctly. Of the four teams selecting COA N, only Team CB10 (ranked tenth) correctly identified the Fulda as unfordable in their solution justification.

Indirect Measures and Participant Judgments

Workload Ratings

All participants rated workload twice. For the structured and computer-supported conditions, workload was rated after gathering of the facts and at the conclusion of the exercise. During the second rating, participants using the structured approach had to provide separate ratings for Steps 4 through 9 of the experimental task. Although the two sets of data are divided into Step 2 and Steps 4-9, the unspecified teams did not have steps specified. Participants in the unspecified condition performed one set of ratings at a time period that corresponded to the end of the "fact gathering" step for the other two conditions; and another set of ratings at the end of their exercise. For

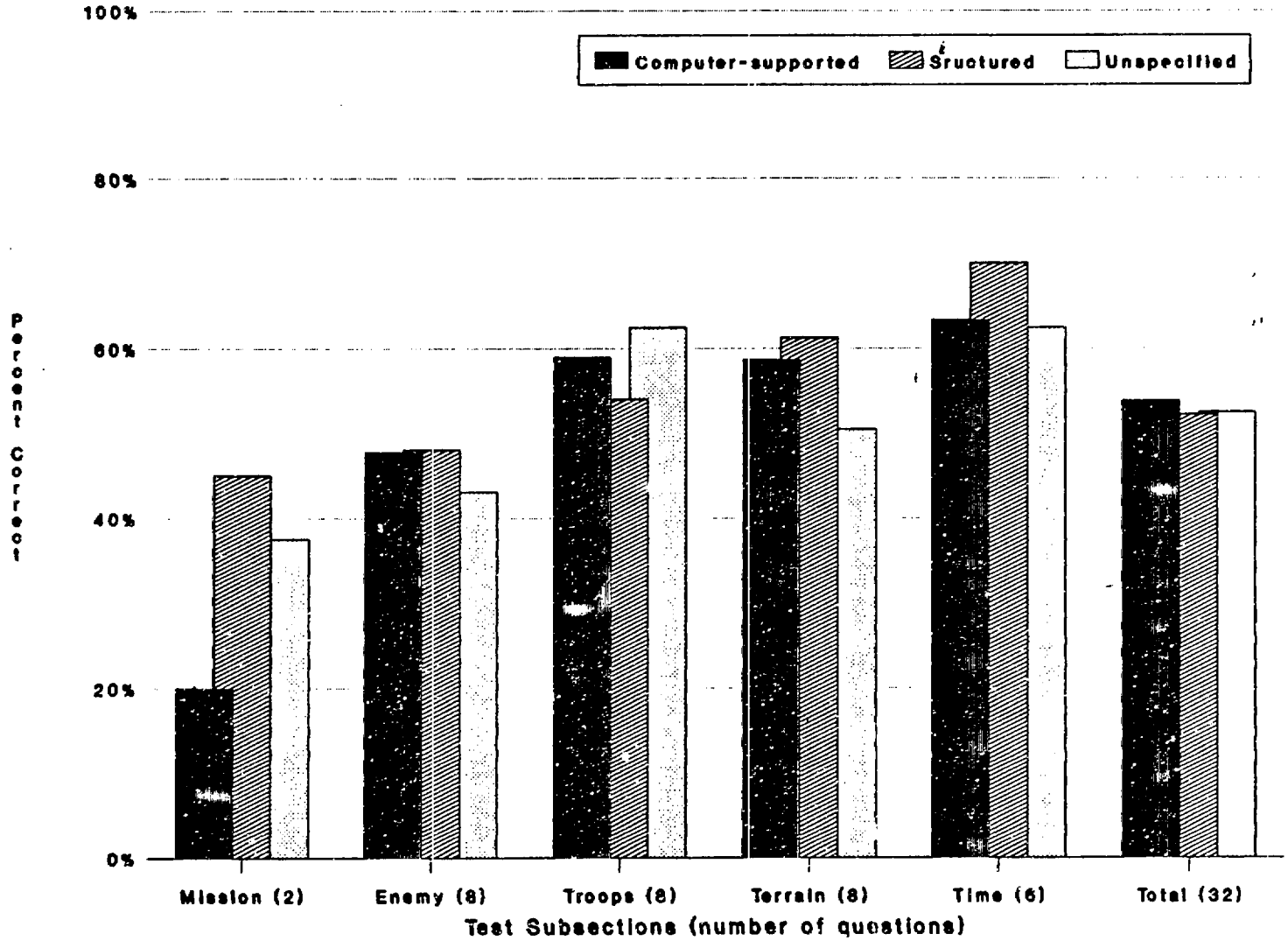

Figure 15. Situation awareness test scores.

Table 18
Situation awareness test's most commonly known and most commonly missed questions

Most Commonly Known Questions (Accuracy ≥ 75%)
Within how many hours of H-hour (051200 Sep) must the division be on the objective?
How many ground maneuver battalions are currently in the reserve brigade?
What type of terrain is most prevalent in the division AO west of the Fulda river?
What is the estimated current strength of the 15 MRD?
Wind direction for the next two days will be generally out of what direction?
Relative to the 16 MID attack, when is the 32 MID attack to begin?
Which of the following is the division commander's preference for force distribution in the attack?
Where is the Fulda river most fordable in the division AO?
Most Commonly Missed Questions (Accuracy ≤ 25%)
Which of the following is not an implied task for the mission of the 16 MID?
Which of the following 15 MRD regiments is equipped with BMPs?
How many times will the division have to cross an autobahn between the current FLOT and the objective?
The 32 AD will relieve elements of the 16 MID on the right (south) flank at what time?
Which of the following best describes the mission of the 313 Sep Mech Bde?
What is the most likely mission of the 10 CAA?
Which of the following was not a special concern of the division commander according to his guidance?

purposes of discussion, workload will be categorized as low, medium, and high for mean values of 1 through 3, 4 through 7, and 8 through 9, respectively.

Examination of workload data for the structured and computer-supported conditions indicated that there were no major differences in ratings across Steps 4 through 9. For this reason, ratings for these steps were averaged for each participant. This procedure also made it possible to compare two sets of ratings for all three treatment conditions.

Figure 16 reveals that workload ratings for all conditions were at medium levels except for physical workload which was rated low. There were no major differences in workload that could be accounted for by treatment condition. The mean ratings were 5.1 for unspecified teams, 5.5 for structured teams, and 5.0 for computer-supported teams. Frustration for the structured condition was in the low-medium range for Step 2 and increased to medium levels for the remainder of the exercise.

COA Task Evaluation Questionnaire

One of the objectives of this experiment was to determine which task steps were performed poorly or are difficult to perform. In addition to the objective measures indicating poor performance in relationship to unspecified and structured procedures and compared to an expert panel, participants were questioned about several qualities of the

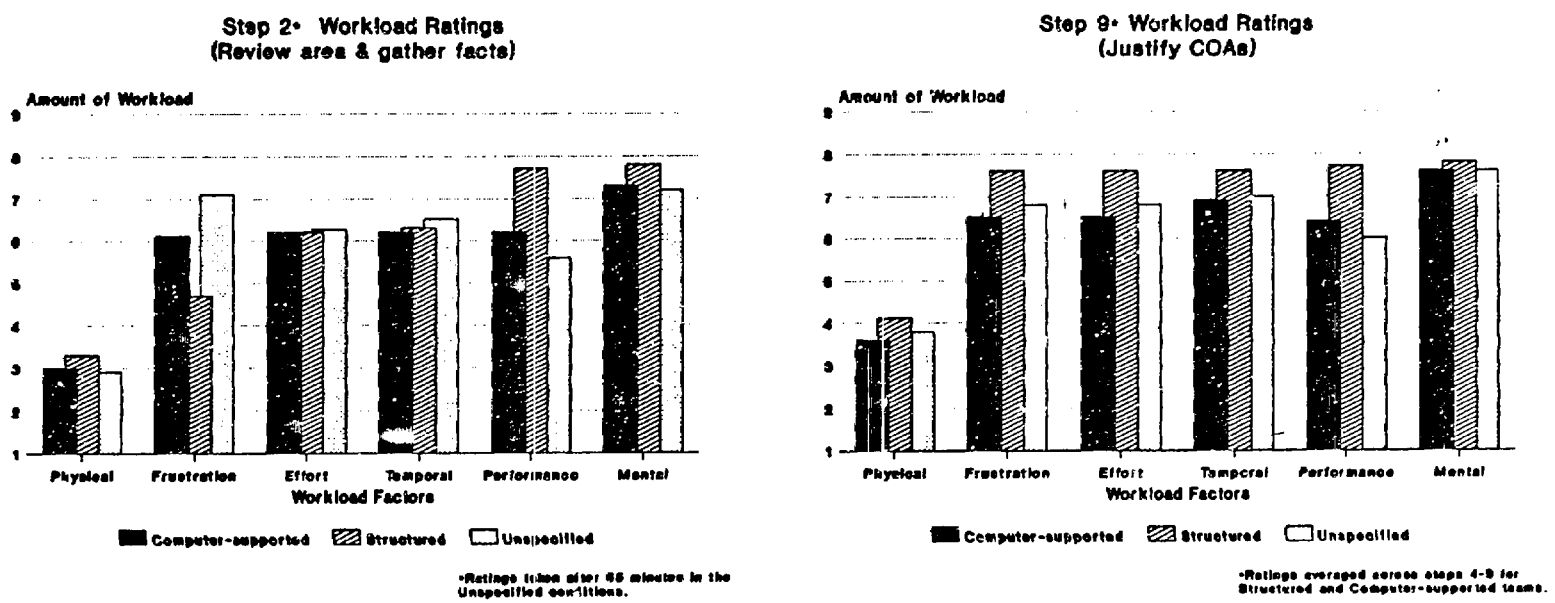

Figure 16. Workload ratings by workload factor, experimental condition, and task step.

task.

One quality was task difficulty. Figure 17 depicts the average ratings for each task step and each experimental condition. Among all task steps, steps 6 and 7 were rated the highest difficulty (3.5 and 3.4 average, respectively), between "some difficulty" (3) and "considerable difficulty" (4). Progressing from the war gaming step to the justification step, difficulty ratings went down by an average of 1.3 for the structured and computer-supported teams, while it only decreased by 0.3 for the unspecified teams. Difficulty ratings by the unspecified teams for step 9 were 0.8 points higher than the structured teams and 1.1 points higher than the computer-supported teams. Having done the structured analysis perhaps made the selection and justification step easier for the structured and computer-supported teams.

Confidence ratings of war game factor estimates were also taken (as described previously, see page 47). The low confidence ratings correspond to the relatively high difficulty rating for war gaming.

Figure 18 shows the amount of effort that the unspecified teams reported for each of the task steps. The unspecified teams did not perform each task step, nor to the level of detail of the other two groups. This figure depicts what they reported. The "octagon" symbols connected by dashed lines depict the average of the four teams. The perceived amount of effort is generally inflated, for example none of these teams aggregated and scaled war game results. Principal activities which were observed (see Table 15) involved assessment and review (step 2), compare COAs (step 8) and justify COA selection (step 9). Team UB09 was observed expending considerable effort arraying forces, but they did not explicitly identify critical events, war game, or aggregate and scale war game results.

Complex Cognitive Assessment Battery (CCAB)

CCAB is an experimental battery of computerized tests which are theoretically related to C2 skill requirements. CCAB was used to acquire baseline ability data to relate to experimental measures of performance. Also CCAB was used to help control the time that the structured and unspecified teams were exposed to the experimental environment. Structured teams were given five of CCAB's nine subtests for one hour, and unspecified teams were given all nine subtests during a two hour period. One data set was obtained from 15 participants on word anagrams (WA), logical relations (LR), mark numbers (MN), numbers and words (NW), and information purchase (IP). A second data set was obtained from six participants on the tower puzzle (TP), following directions (FD), route planning (RP), and missing items (MI). (Data for one unspecified team [UB04] and one structured team member [SA13] were lost due to a computer error.)

For an average of the five subtests, fourteen of the 15 participants scored within one standard deviation of norms based on 51 college students (Sprenger & Fallesen,

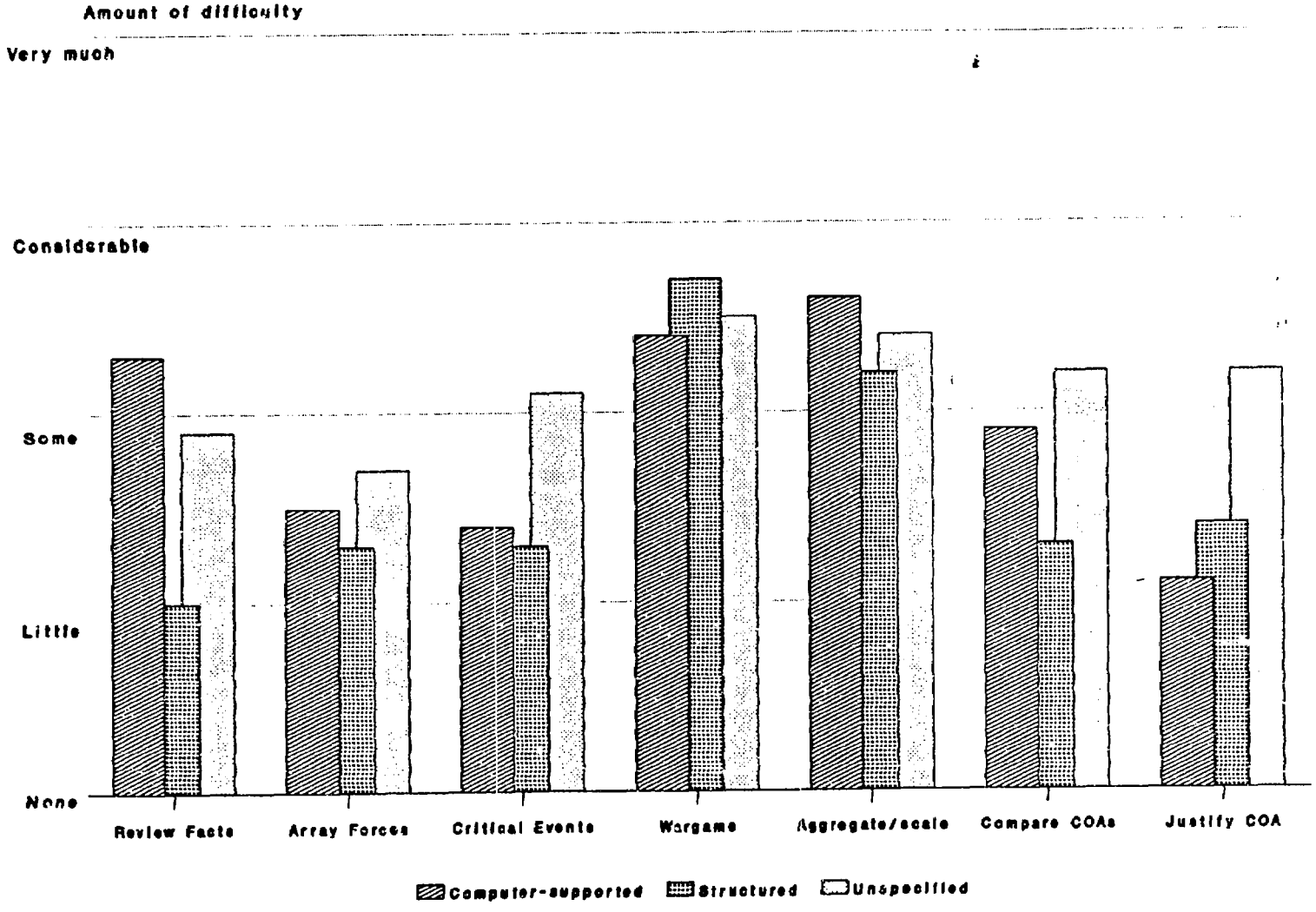

Figure 17. Difficulty ratings for COA analysis tasks by experimental condition

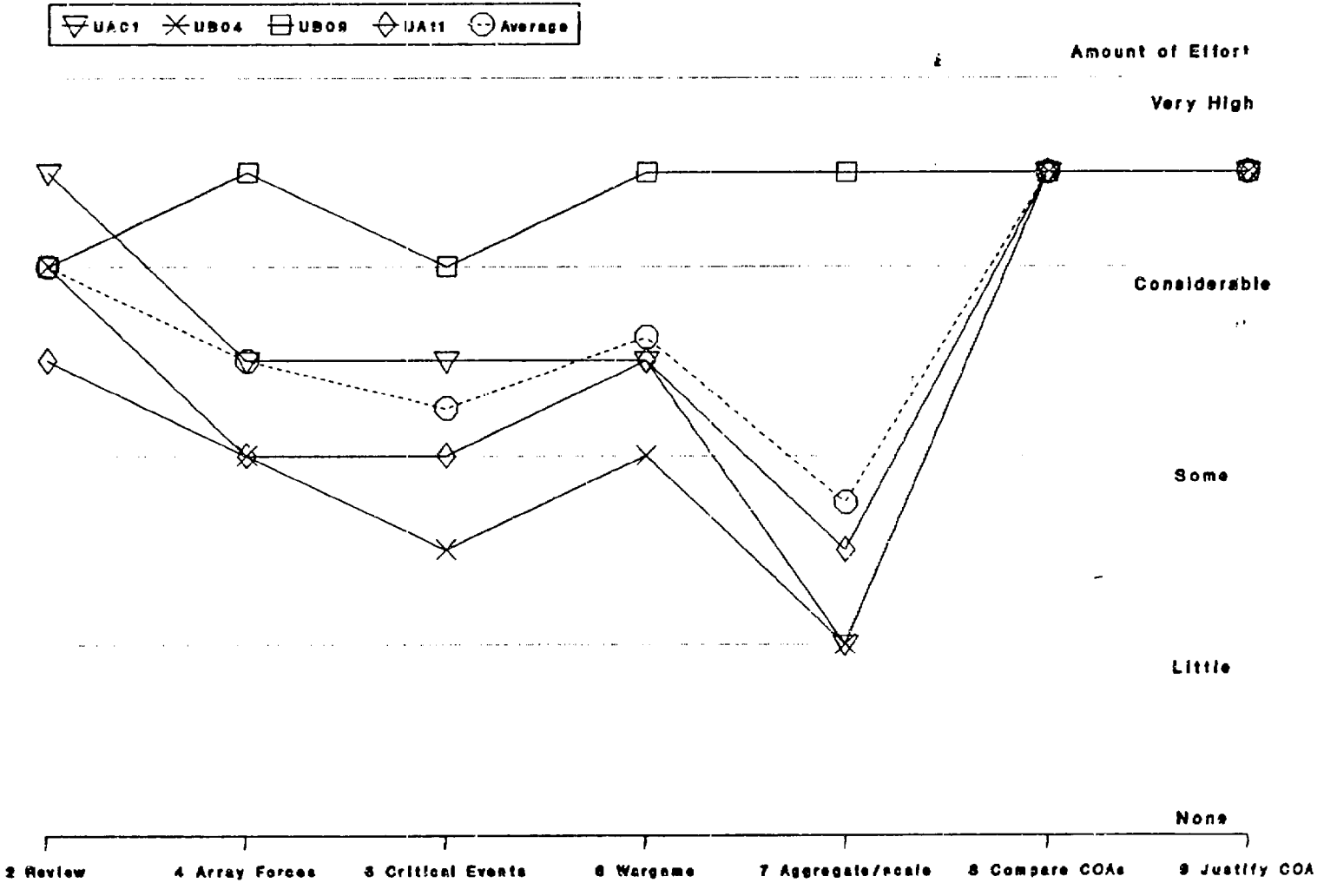

Figure 18. Effort reported by unspecified teams for each task step.

Table 19
Spearman's correlations and significance levels of CCAB subtests with Solution Justification Rankings and Situation Awareness Test Scores

Participants Taking CCAB Subtests	CCAB subtests	Situation Awareness Test		Solution Justification	
		Correlation	α	Correlation	α
Unspecified and structured (n=15)	Word anagram (WA)	.4438	.05	.0046	.87
	Logical relations (LR)	.1580	.58	.2473	.38
	Mark numbers (MN)	.1652	.56	**.5643**	**.03**
	Numbers and words (NW)	-.2065	.46	.1116	.70
	Information purchase (IP)	.1848	.52	**.5509**	**.03**
Unspecified (n=6)	Tower puzzle (TP)	.6000	.23	.3857	.48
	Following directions (FD)	.7714	08	-.5286	.30
	Route planning (RP)	**.8857**	**.02**	-.0714	.90
	Missing items (MI)	.7714	.08	-.3000	.59

1989). The other participant scored at the seventy-fifth percentile (assuming a normal distribution).

Table 19 gives CCAB subtest correlations with the situation awareness test scores and with solution justification rankings. There were no differences on the five subtest scores between the unspecified and structured teams, indicating no ability differences in group make-up. Differences on MN and IP subtests did approach a significant level, (α=.06) with the unspecified teams having higher scores. Both the MN and IP subtests correlated significantly with the ranking of solution justification (Spearman' correlation with MN = 0.56, α=.02, Spearman's correlation with IP = 0.55, α=.03), indicating poorer CCAB subtest scores with better rankings (see Figures 19 and 20).

CCAB subtest scores were also correlated with the situation awareness test scores. Route planning had a significant correlation with the situation awareness scores (better on CCAB-RP, better on situation awareness test) (see Figure 21).

Data Importance

After the exercise, participants were asked to rate the importance of situation and reference data elements. For situation data elements, participants selected the top six out of 20 data categories and ranked those six in order of importance. The rankings

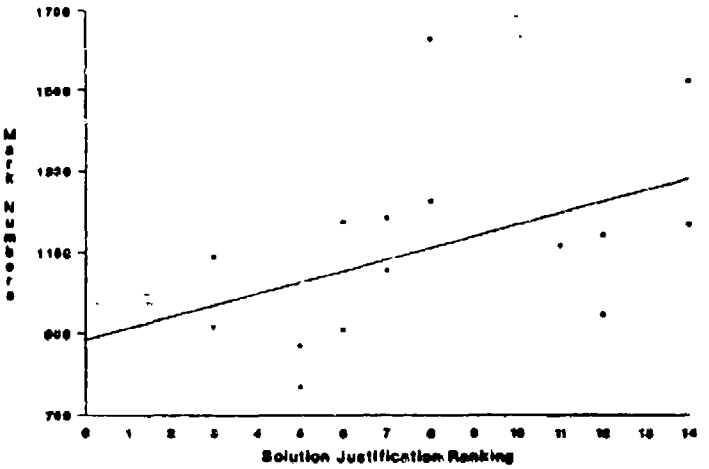

Figure 19. Relationship of solution ranking and CCAB's mark numbers.

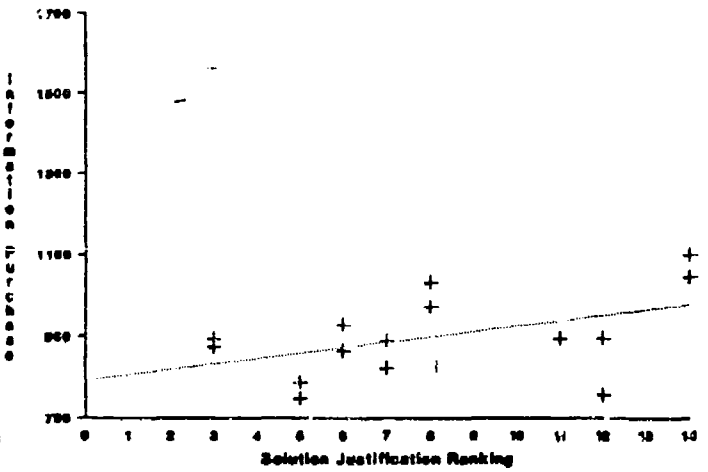

Figure 20. Relationship of solution ranking and CCAB's information purchase.

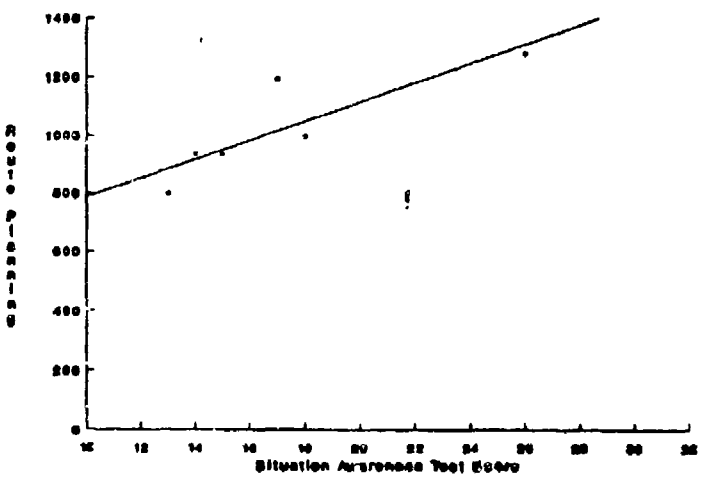

Figure 21. Relationship of situation awareness and CCAB route planning.

were combined across participants to compute a weighted average used to rank the order of importance of the situation data category. The situation data category and their importance rankings are given in Table 20. These rankings were compared to similar data categories from an experiment by Michel and Riedel (1988). There were no significant differences in the two sets of rankings (Mann Whitney z statistic = 0.2583, α=.80), though the rankings have a fairly low correlation (Spearman's correlation = .1391, α=.60).

Also participants ranked the importance of reference data. The top four categories were selected from 13 elements and also ranked in order of importance. The corresponding data are given in Table 21.

Human-Machine Interface Design

The Human-Machine Interface questionnaire provided feedback from the participants on (a) ease of use for workstation features and (b) preferences for various map features. Ease of use questions for one set of questions required participants to rate a feature or capability from 1 to 5; 1 represented "hard to use", 3 was "OK", and 5 was "easy to use".

Gathering and identifying the facts required access to Situation and Reference data bases in the Tactical Planning Workstation. The ten participants from the computer-supported condition gave a mean rating of 3.9 (range 3 to 5) when asked how well the data bases were labeled and organized for easy and logical access. Maps provided critical information for analyzing tactical course of action. Participants gave a mean rating of 3.8 (range 2 to 5) when asked whether map displays were laid out in a logical manner so that they could find the information quickly. Several respondents identified problems with scrolling maps. Map backgrounds, scales, and map features were all rated an average of 4. All map labels were unanimously judged as consistent with standard Army usage.

A low rating for a set of features (e.g., map scales) indicates the most useful and the highest rating indicates the least useful. The **map scales** of 1:80,000 (mean = 1.6 on a 4 point scale) and 1:160,000 (mean = 1.6) were clearly more useful compared to the 1:400,000 (mean = 3.1) and 1:800,000 (mean = 4) scales. Of **map features**, grids (mean = 2.4 on a 6 point scale) were marginally preferred over roads (mean = 2.9), built-up areas (mean = 3.0), contours (mean = 3.0), and hydrography (mean = 4.2). Miscellaneous features were least useful (mean = 5.4).

The Tactical Planning Workstation has four map background options: vegetation (the default background), shaded relief, elevation banding, and null. There was a slight preference for the shaded relief (mean = 2.2) and elevation banding (mean = 2.3) over null (mean = 2.8) and vegetation (mean = 2.9) backgrounds, but the null background was selected the most times (4) as the first choice.

Table 20
Data importance rankings

Situation Data Category	Staff Area	Participants selecting element	Weighted Average	Rank
Div Cdr's guidance	G3	25	1.6	1
Corps FRAGO	G3	20	1.8	2
Weather history	G2	2	2.0	3
Tactical overlay	G3	17	3.1	4
Intelligence estimate	G2	21	3.3	5
OPFOR composition	G2	12	3.5	6
Current operations	G3	8	3.6	7
Task organization	G3	15	3.8	8
OPFOR artillery	G2	1	4.0	9
OPFOR committed	G2	5	4.2	10
OPFOR reinforcements	G2	3	4.3	11.5
Intelligence reports	G2	3	4.3	11.5
Personnel strengths	G1	9	4.9	13.5
Personnel estimate	G1	8	4.9	13.5
Class III (POL)	G4	1	5.0	15
Logistics estimate	G4	11	5.1	16.5
Equipment status	G4	7	5.1	16.5
Weather forecast	G2	1	6.0	18.5
Class V (ammo)	G4	1	6.0	18.5
Losses and gains	G1	0	-	20

Table 21
Reference data importance

Reference Data Category	Staff Area	Number participants selecting data element in top 4	Weighted Average	Rank
Organization	G3	20	1.3	1
Intell composition	G2	18	2.1	2
Equipment	G3	11	2.4	3
Strengths	G2	18	2.7	4
Battle losses	G1	2	3.0	5
Strengths	G1	17	3.3	7
Intell equipment	G2	7	3.3	7
Equipment characteristics	G3	4	3.3	7
Supply	G4	5	3.4	9
POW	G1	0	-	-
Equipment characteristics	G2	0	-	-
Minefields	G3	0	-	-
Transportation payload	G4	0	-	-

To conduct the experimental task, understanding of the tactical situation required access to both BLUE and OPFOR unit information and control measures. Participants rated the BLUE UNIT information (mean = 1.6) the most useful. A moderate preference was expressed for OPFOR Unit information (mean = 2.1) and BLUE countermeasures (mean = 2.9).

Ease of use was also assessed for workstation interface using a rating scale of 1 to 5 with verbal anchors of "Difficult (1)", "Somewhat Difficult (2)", "Somewhat Easy (3)", "Easy (4)", and "Very Easy (5)." With this scale, COAAT was considered to be between "somewhat easy" and "easy" to use for assigning critical events (mean = 3.4) and easy for inserting and aggregating war gaming measures (mean = 4.0). Participants also considered it "easy" to "very easy" (mean = 4.5) to coordinate use of the Sun and Symbolics workstations while identifying critical events.

Participants also gave mean ratings of 3.6 and 3.8 for ease of use of "walking" menus and the Task Organization Tool (TOAST), respectively. These ratings are

between the "OK" scale value of 3 and the "easy to use" value of 5.

Summary of Debriefing Questionnaires

At the conclusion of each exercise, the participants were asked to complete questionnaires concerning the day's activities. After completing the questionnaires, the participants were debriefed by the experimenters using interview questions developed in advance for each of the three conditions. Table 22 provides the tabulation of responses to questions on difficulties, adequacy of time and information, and automation suggestions. Table 23 provides the tabulation of responses to questions unique to each team in the three conditions. The following summarizes the highlights of participants' responses.

- War gaming is an important task, but it is time-consuming and complex.

- Locating and using appropriate reference material to support war gaming is difficult.

- A majority of the experiment participants indicated a low level of confidence in their ability to war game and visualize the battle.

- Simplified, easy-to-access checklists would be a definite help.

- Automation would assist war games by providing correlation of forces, combat power ratios, time-distance calculations, attrition, logistics consumption data for selected classes of supply, digitized terrain, range fans, and assorted checklists.

- The Tactical Planning Workstation was viewed as easy to learn and use by most participants. The major area of difficulty seemed to center around using computer-displayed maps.

- A majority of the participants would have liked to have had access to a printer to create a paper environment that they are more comfortable with.

- Computer-supported participants were quickly able to learn the operation of the Tactical Planning Workstation and COAAT. (It should be noted that, even though they were able to operate the system effectively for the specific experiment, they did not have the opportunity to develop real proficiency and exploit many of the advantages of automation.)

Table 22
Summary of responses to debriefing questions that were common to unspecified and structured teams.

Question	Response	Unspecified (n=4)	Structured (n=5)
What major difficulties did you have in COA analysis?	War gaming and predicting.		4
	Becoming familiar with the problem.	3	
	Visualizing the battle.		1
	FMs do not provide enough guidance.	1	
Was there enough time to perform the task?	Time was adequate.	4	5
	But it was constraining.		2
	Would have used more if it were available.	1	
	Would have liked to think about the problem over night.	1	
What additional information is necessary to perform the task?	Information was adequate.	2	
	More logistics data.	1	2
	CENTAG mission & intent.	1	
	Something to capture unit locations for visualization.		1
For what functions would automation be useful?	Yes, automation would have been useful.	3	3
	Force ratios.	3	1
	Time & distance calculations.	3	1
	Planning factors.	3	
	Logistics consumption.	2	
	Attrition rates.		1
	Checklists.		1
	Word processing.		1
	Range fans.		1

Table 23
Debriefing questions unique to each experimental condition.

UNSPECIFIED		
Did you develop a plan for working on the problem?	No, no specific plan or team member assignment.	4
	Used a "least regrets" method.	1
	Would have worked better with a plan.	1
What process did you use to analyze COAs?	Used ST 100-9 as a guide.	3
	Used FM 101-5 for format.	1
	Tried action-reaction war gaming but not successful (also unsuccessful in CGSOC).	1
	Tried to find criteria to justify selection. Battle measures were too abstract.	1
	Reviewed Corps FRAGO and Div. Cdr's guidance for factors and weighted them.	1
	Most important factor was enemy disposition.	3
	Most important factor was own force's ability to mass and maneuver.	1
	Tried visualizing battle, but had too little experience or time for only 1 COA.	2
	Calculated time requirements in relative terms (faster - slower).	2
STRUCTURED		
Did the 9 step process provide the structure necessary to perform the task?	Yes, it was helpful and consistent with ST 100-9 and instruction in CGSOC.	5
	War gaming is difficult and time consuming.	3
	Lacked confidence in predicting outcomes.	2
	Task was more difficult than in CGSOC because did not have as many officers for support and did not have 3-4 days to work the problem.	2
	Process focuses on peace time training, may not be time to apply it in war time.	1
	Process should have reminders of the battlefield framework and operating systems.	1
	Automation tools should calculate battle outcomes.	1
Did the work sheets assist in performing your analysis?	Yes, the work sheets assisted in organizing and analyzing data.	5
	Work sheets were used as checklists.	3
	Difficult to provide battle outcomes; the Army does not have a standard.	2
COMPUTER-SUPPORTED		
What was most difficult in operating the Tactical Planning Workstation?	Sensitivity of the mouse using the walking menus.	5
	Unfamiliar with computer-generated maps.	3
	Holding mouse button down while using the walking menus.	2
	Map scroll bars, should have a reference system.	1
What changes would you recommend to the Workstation?	Provide a printer to provide screen dumps of selected information.	5
	Automate many of the war gaming functions.	1
	Install COAAT on the Sun workstation.	1
	Put more flexibility into the editing of COAAT.	1
	Change walking menus so the button does not have to be held down.	1

SUMMARY AND DISCUSSION

The experimental task of analyzing tactical courses of action was performed under three conditions. Participant teams in the unspecified condition were allowed to perform the task using a procedure or process of their choosing. This formed the baseline condition to assess potential performance enhancements resulting from the use of U.S. Army prescribed procedures imposed under the structured and computer-supported conditions. Comparing the results of these two groups also addressed whether or not computer support would further increase the likelihood of performance enhancement when a procedural approach was imposed upon decision making.

Teams had to choose between two alternative courses of action. The preferred or "benchmark" decision was based on the expert panel which developed solutions for each step of the task.

Limitations on the Generalizability of the Experiment

Generalizability is the degree to which findings from this experiment apply to the broader environment which was represented.

A fairly rigorous experimental paradigm (for this tactical domain) was used to ensure standardization in scoring and for comparing manual, structured procedures to computer-support. For example, teams in all conditions were given a list of assumptions near the beginning of the task. Structured and computer-supported teams were given standard lists of facts and force array after they had completed those steps. While this enhanced the ability to standardize scoring procedures and compare between the teams, it also may have "leveled" the structured and computer-supported teams' information and performance.

The small sample size limited the statistical power[1] of the tests and complicated interpretation of the results. To overcome the limitations of small sample sizes, considerable effort was put into diagnosing the behaviors. All statistics were treated as exploratory, with nonparametric statistics frequently used, and the actual value at which the null hypothesis would be rejected (i.e., α) was reported.

Participants

Experience and background of participants for the three conditions were similar. Three or four of the participants in each condition were from the combat service support branch, the other participants were from combat and combat support branches. One of

[1]Statistical power is the likelihood of correctly rejecting a hypothesis when it is actually false.

the four unspecified teams knowledge was judged adequate compared to four for structured and three for computer-support. Five of the seven teams ranking in the upper half of solutions were judged to have adequate knowledge, and three of seven in the poorer half were. The difference is not significant and is even more interesting when one considers that the second best team was judged not to have adequate knowledge, while the last place team was judged to have adequate knowledge. There was no trend between the quality of solution and the combat/combat support and combat service support make-up of the teams.

Task Performance

Analysis of results was done on the decision making process. The following summarizes the results as they pertain to the procedural steps used during decision making.

Pertinent Facts (Step 2)

According to training on the estimate, a preliminary analysis should be conducted to identify the pertinent facts. For the experiment, there were no differences in the average number of facts identified across conditions. Teams provided a surprisingly low percentage of the expert-identified facts. There was not a single fact that was listed in common by every team. None of the facts were listed by all teams. There were only a few facts that were listed by the majority of the teams. Participants may have had insufficient practice performing this step, there may have been uncertainty as to what constituted a pertinent fact, or individual differences in what is considered important may be the most dominant effect. Explicit identification of facts is seldom seen in command post exercises. Facts were sometimes mentioned later in the experiment after the step had been completed. While teams were supposed to record and update pertinent facts throughout the task, they never returned to the formal step of recording additional or changed pertinent facts.

Arraying the Forces (Step 4)

Friendly forces must be arrayed and task organized to ensure an acceptable probability of mission success based on the commander's guidance. Only one of the unspecified teams arrayed forces and calculated combat powers and ratios. All teams in the structured and computer-supported conditions allocated less combat power to the main attack than the experts. Failure to allocate all of their available combat power was often due to inadequate use of aviation assets and field artillery. None of the treatment manipulations "guaranteed" adequate consideration of combat resources. There were not explicit instructions telling them to use all available combat power, nor did COAAT indicate anything about available or remaining combat power. In the future, procedures or computer support should be specifically designed to address the problem.

Critical Events (Step 5)

Critical events are those explicit and implicit tasks that are paramount for mission success. There was no difference between the structured and computer-supported conditions in the number of critical events they identified in common with the expert panel. The teams identified critical events, accurately matching a high number of the expert-identified critical events. However, the teams also identified noticeably more critical events than the expert panel, particularly for the supporting attack. Observations suggest that the teams were overly optimistic about the extent to which follow-on actions were feasible after the first critical event of the supporting attack. Only one unspecified team identified critical events, and they did not use them subsequently to war game.

War Gaming (Step 6)

War gaming required teams (using a prescribed procedure) to make quantitative predictions for objective and subjective factors. Eight objective or battle outcome factors were presented to participants along with five subjective factors. For a particular factor, COA comparison focused on the relative values for the two courses of action to identify the favored COA for that factor. Aggregate scores for both objective and subjective factors were also calculated by the structured and computer-supported teams. None of the unspecified teams war gamed quantitatively.

Of the objective factors, the expert panel considered friendly equipment losses, enemy equipment losses, and battle duration as the most important. There were no statistical differences between the structured and computer-supported teams' estimates or differences from the experts on these three objective factors. The variability in the teams' estimates was high, which is another indication of the low confidence that the participants reported in their estimates. Both groups underestimated friendly losses for both COAs. The structured group overestimated enemy losses for both COAs. All seven teams using battle duration underestimated the duration of COA N.

The teams did differ from the experts in the direction of the advantage between the COAs. Seven of eight teams favored COA N on friendly losses, while the experts gave the advantage to COA S. Six of six teams favored COA S on enemy losses agreeing with the experts. Only three of seven teams agreed with the experts in favoring COA S on battle duration.

These results suggest notable difficulties of participants to accurately predict time and space relationships of the battle.

Scale and Aggregate Battle Results (Step 7)

The objective and subjective factors that were weighted heaviest by the expert panel were generally weighted high by the participant teams. Experts considered two

objective (battle duration and friendly equipment casualties) and two subjective factors (mission accomplishment and flexibility) as being most critical. Participants weighted two of these factors (mission accomplishment and battle duration) very comparably with the expert panel; however, two factors (friendly losses and risk) were weighted lower by the participants than by the panel.

Generally, scale values did not strongly favor one COA over the other for the objective measures. The experts did not have a scale value difference for enemy or friendly equipment losses; only battle duration. A team's scale values for the two COAs rarely differed by more than one.

Comparison of COA (Step 8)

The percentage difference between the objective scores (weighted and summed) for the two COAs was typically small (less than 6 percent). This was not true for subjective factors. Projections for a particular factor by teams were often noticeably different (at least greater than 18 percent) for the two COAs. The subjective factors for this scenario provided the best discriminators for selecting a COA. Three of the teams went against the direction of their objective factor advantage and made their selection, presumably, based on the subjective factor difference between the COAs. In fact, the team's subjective score favoring a COA corresponded perfectly with the COA which was eventually selected by that team.

All of the structured teams were observed to perform error-checking at some time during the overall task, showing that they were aware that it should be done; but most of them experienced arithmetic errors in their weighting or addition. None of the computer-supported teams made comparable errors because of the spreadsheet tool (COAAT) available to do the calculations.

COA Decision and Justification (Step 9)

Teams under all experimental conditions were required to choose a preferred course of action and to provide justification for the decision. For purposes of analysis, information for the justification was obtained from the team's list of advantages and disadvantages for each course of action and from a paragraph that was written to justify the decision.

The groups differed significantly in the merit of their justification for selection of COAs. Computer-supported and structured teams ranked significantly higher than the unspecified teams. Three teams (2 computer-supported and 1 structured) reached the maximum possible score for the merit justification measure. Two unspecified teams received no points at all. The four teams selecting COA N ranked tenth, eleventh, twelfth, and fourteenth.

The computer-supported and structured teams received more procedural guidance than the unspecified teams. The unspecified teams did not follow the same procedures as required of the other two groups (and included in the estimate of the situation). Only one of the four unspecified teams arrayed forces (quantitatively), and only one team identified critical events. None of the unspecified teams performed war gaming of critical events, and they did not scale or aggregate battle results.

As it turned out the estimation of battle results by structured and computer-supported teams distinguished very little between the two COAs. However, by having to make these estimates for critical events, the structured and computer-supported teams were forced to visualize a level of the dynamics of the battle that the unspecified teams did not do explicitly. Although many times the structured and computer-supported teams were making unsophisticated guesses to satisfy the spreadsheet with a number, they did address each critical event in sequence. There was very little projection or visualization by the unspecified teams. They made comparisons on the face value of the information without considering the dynamics and interaction of battle events and battlefield systems.

Performance Times

The time to complete the experimental task was controlled with guidance in instructions and while monitoring the performance. The intent was to let the participants control the time spent on each step, but total participant control would have risked uncompleted tasks. Although not entirely free to vary, time was analyzed as a dependent variable.

There were no significant differences among the experimental conditions, but the computer-supported teams tended to take longer on the average. There was also a trend (non-significant) for faster times to lead to poorer solutions. This was especially true for the critical event step times which had a significant negative correlation with solution ranking. This might be because spending more time considering the critical events provides a better understanding or an indication of a greater desire to understand the future action. An alternative explanation is that it took longer to enter the critical events into COAAT and that the teams using COAAT did better overall.

A special case of time was considered. Participants were asked and were observed to see if they made a COA determination prior to the formal selection step, referred to in the standard training materials. The experimental guidelines allocated 85 percent of the task time prior to when a selection was to be made; while the remaining 15 percent was for justifying the selection. All but one team used less than 85 percent of their time before a selection was made. Four teams used less than 50 percent of their total time. No penalty resulted to those teams making early decisions. Also there was no primacy (or "stubbornness" or "evidence marshalling") bias, as five "early decision" teams eventually switched their selection.

Other Performance Indicators

Performance Style

The teams were observed to have poor task organization skills. Nine of the teams made no conscious effort to organize and allocate work. This is especially surprising because, even though members on some teams were previously acquainted with one another, none of them performed this type of work together before. Six of the nine failing to organize were in the poorer half of the solution rankings. Nine of the teams did not perform ongoing management of their work.

None of the computer-supported teams exhibited behaviors normally associated with the phenomenon of "groupthink", while five of the nine unspecified and structured teams did. The computer-supported teams tended to have more of the qualities (i.e., balanced team effort, equal status on team, subordinate acceptance of role, one member not dominant in knowledge or motivation) associated with cohesion and cooperation than the other teams. This points to the importance of cooperation and consensus-building, in contrast to adhering to strict hierarchies or agreeing just to avoid conflicts.

In all cases a leader-subordinate relationship emerged. In at least one team the roles switched as one member took charge from the other. Leaders in the better half of the solutions were all judged adequate by the observing experimenters, while only 3 in the poorer half were judged adequate.

Situation Awareness

There were no significant differences among experimental groups in participants' situation awareness accuracy. The participants scored an average of only 54 percent correct on this multiple choice test. The most interesting question pertaining to the scoring of solutions concerned the fordability of the Fulda river. Five of seven participants answering incorrectly were on the poorer scoring teams.

Workload Ratings

Participants were required to provide their perceptions of workload imposed by the experimental task and conditions. Workload was partitioned into the areas of mental demand, physical demand, temporal demand, performance, effort, and frustration. Workload for these six dimensions was categorized as being either low, medium, or high.

Workload assessments were critical for addressing several issues. In general, workload was assessed to determine if using a structured approach to decision making increases workload. It was also predicted that use of computer support would reduce workload imposed by use of a structured approach but, from a practical perspective, there was concern that use of computer support could actually increase workload. It is

not uncommon for a computer system to shift the user's requirements from calculations and other reasoning skills to lower level data entry skills. The shift may result in increasing workload. If the computer does not "fit" well with how the users perceive their jobs, the mismatch can cause an increase in workload as the user might try to perform their tasks both with computer-support and manually.

There were no significant workload differences among the experimental conditions. Workload levels were at medium levels for all areas, except for physical demand which had a low level. The small sample size is an obvious constraint, but generally, there was no indication (a) that use of a procedure imposed more workload on the participants and (b) that computer support made the job easier. While computer capabilities did not decrease workload, it is also encouraging that workload was not increased, especially since the level of training was relatively low and practice was nil. Only two hours of training and experience were provided in using and understanding the computer-based systems.

Course of Action Task Evaluation

Participants were asked to rate and comment on various characteristics of the task steps. War gaming had the highest average difficulty rating, which is corroborated by the fact that the unspecified teams did not even perform it. The perceived difficulty of the selection and justification step was lower for the structured and computer-supported teams than for the unspecified teams. This suggests that having done war gaming, though it is difficult to do, makes the selection and justification easier.

Complex Cognitive Assessment Battery (CCAB)

There were no differences between the unspecified and structured participants taking the same five CCAB subtests. The "Mark Numbers" and "Information Purchase" subtests were the only ones having a significant correlation with solution ranking. The correlation was in the opposite direction from what was expected: poorer CCAB performance led to better rankings. "Route planning" had a significant positive correlation with the situation awareness test. These subtests should be studied further to determine if they indeed are testing skills or abilities which correspond to performance, or if the significant correlations are happening by chance.

Data Importance

There were two broad classifications of tactical data available in this experiment. One was reference data, indicating typical base information which a planner could use in force projections, war gaming, or better understanding of possible force structures and capabilities. The five top-ranked reference categories were organizations, intelligence, own equipment, enemy strengths, and own personnel battle loss percentages. Situation

data were made up of information about the tactical events which occur and their resulting effects on force status. The five top- ranked situation data categories were division commander's guidance, Corps FRAGO, weather history, tactical overlay, and the intelligence estimate.

Human-Machine Interface Design

A questionnaire was used to obtain opinions from participants on human factors considerations related to computer support. Despite limited training with the computer systems, participants indicated no significant problems associated with accessing data bases, and generally, the computer support provided by the COAAT was considered "somewhat easy" to use.

The questionnaire also addressed user preferences for the utility of certain features of the computer-support systems. The Tactical Planning Workstation had four map scale options, and generally, participants preferred to work with the two larger scale maps (1:80,000 and 1:160:000). For the map features, participants found map grids slightly more useful than roads, built-up areas, and contours while miscellaneous features were not very useful. Participants also showed a slight preference for the shaded-relief and elevation-banding map backgrounds, but the null background was most often picked as the first choice. More frequent use of null background was also found by Michel and Riedel (1988). Most teams indicated that the mouse was too sensitive, i.e., it required exceptionally fine motor control to perform distinct operations (especially on the walking menus).

Participant Comments During Debriefing

Each participant team was asked a set of questions at the conclusion of the experiment. The following summarizes comments of participants.

From the participants' perspective, one of the most difficult tasks of the experiment was understanding the problem. This is a common comment for experiments using tactical decision making tasks. In a typical staff operation setting in the field, staff officers are likely to have been involved in the garrison preparation for the exercise. In actual combat, officers would form their understanding differently, based on a longer period of time in the situation. Understandings would develop over time based on changes in an evolving situation. New information would be compared to the last understanding of the situation. In this experiment, participants were virtually "thrown into the problem." Although the scenario dealt with combat in an established theater, the rapid understanding required of staff officers might be more typical of possible future, rapid response conditions.

All participants who were asked about the utility of the structured approach felt that it was helpful to use the procedures and that the steps were consistent with current

instruction in CGSC. For the structured conditions, the work sheets were considered to be useful job aids in their own right for organizing and analyzing data. Some participants expressed problems in providing the battle outcome predictions which corresponded to their low confidence ratings. Current U.S. Army procedures and data bases for making outcome predictions were considered inadequate. War gaming is considered necessary, but it is difficult and time consuming.

Certain computer capabilities (separate from those used in this experiment) were considered critical by participants. Computer tools were believed to be necessary for correlation of forces, calculation of combat power ratios, estimation of attrition, estimation of time and distance parameters, and preparing range fans. Other functions would include display of check-lists to use as job aids, word processing capabilities, and most importantly, a printing capability to provide hard copies of screen displays and computational results.

Participants did have some problems with computer support. Use of computer-displayed maps posed problems for several participants. Familiarity and experience with paper maps was a basis for this problem. In addition, the limited display size for maps made it difficult for participants to see the "big picture."

Summary

Unspecified versus Structured Procedures

Comparison of unspecified and structured procedures was possible by observing the procedures used by the unspecified teams compared to the procedures required of the structured and computer-supported teams. The unspecified teams knew about the estimate and actively sought guidance from FM 101-5 and ST 100-9. There were significant differences between the conditions in that the unspecified teams, individually or as a group, did not follow a systematic series of steps. The most systematic team from the unspecified condition spent almost their entire time calculating combat power values and ratios, but did so from a static look at the initial dispositions. They did not do war gaming. The quality of the solutions differed with the unspecified teams doing significantly poorer than teams following structured procedures. The structured procedures led the teams to produce interim results which distinguished very little between the COAs. However, the procedures appeared to force the structured (manual and computer-supported) teams to do a detailed enough analysis to make logical conclusions about the relative feasibility of the two COAs.

Had officers with greater experience in tactical planning and battlefield operations participated, it is envisioned that they would have been able to more readily see the risks and opportunities in each course of action. It is likely that experts would not (and do not) tolerate a slow, rigid, and arduous process which might only show inconsequential differences in combat outcomes or with outcomes that are largely uncertain.

A challenge for refining estimate procedures is to find a balance between steps and sequences of steps which can be used to

- Apply the estimate in the most efficient manner possible,
- Be systematic enough to reduce the occurrence of groupthink and other biases,
- Preclude undertaking steps with little value, and
- Avoid over-quantifying uncertain events and outcomes.

Manual versus Computer-supported Implementation of Decision Making Procedures

Identification of pertinent facts, arraying of the forces, critical events, and war gaming provided a means to compare the relative effectiveness of manual versus computer use of prescribed procedures during decision making. While the small sample size limits the certainty and generalizability of this comparison, the data suggest that there are few differences. Both structured and computer-supported conditions led to similar performance on identification of pertinent facts, arraying forces, critical events, and war gaming. Also there was no difference in solution quality between the two conditions.

Those in the computer-supported condition had no errors in arithmetic calculations because of the COAAT tool, while most of the structured teams made errors. The errors were not severe enough to make a difference in their outcomes, but it is likely that the high propensity for error could lead to incorrect decisions and outcomes in other instances.

Decision and Its Justification

Deciding on a COA in combat can often be a matter of determining the worst of "evils". In this experiment, the "most critical" event for COA N required an opposed river crossing across an unfordable river at night. The perils of this situation had to be carefully considered against problems associated with penetrating a numerically superior enemy for COA S.

Observations of participants' performance suggest that decisions were often based on the criticality or difficulty of the actual event, and not the quantitative predictions. Along this line, the phrasing of subjective factors (e.g., risk) provided a means for participants to "pigeon hole" their qualitative observations and analyses that considered the interaction of several factors.

Procedures for comparison of COAs were based on a linear model that generated aggregate scores for both objective and subjective factors (Steps 8 and 9). The utility of

such a model should be questioned. The river crossing operation for COA N is an example of how the interaction effect of many factors can be a key factor in the decision. The factors of terrain (a river), environment (night), friendly operations (a river crossing). and enemy considerations (a dug-in defensive position) combined to create a difficult and complex operation. The complexity of this situation makes it that much harder to predict battle outcomes. And once quantitative projections were made, it was easy for the predictions of a single event to get "washed out" when it was rolled up with other events to produce an aggregate score.

Using a decision analytic approach, as complicated as a weighted, multi-attribute utility matrix or as simple as summary columns of pluses and minuses, can be misleading for complex, dynamic tactical problems.

CONCLUSIONS AND RECOMMENDATIONS

This experiment examined the impact of procedural structure and computer support on the selection of a tactical course of action by Army officers role-playing as division plans officers. Experimental results and comments from participants indicated the potential benefits of using a structured process for tactical decision making. Using a structured approach increased the likelihood that critical factors were considered in the decision making process. Even when the structured procedures produced a marginally informative outcome, such as showing little or no distinction in objective war gaming scores, going through the process helped to achieve a deeper level of understanding of the tactical operation than those not required to follow structured procedures.

The estimate of the situation has been undergoing refinement throughout its life (Michel, 1990). The format of the estimate in 1932 had 13 topical headings. In 1984 the format grew to 29 headings with additional, separate estimates on personnel, intelligence, logistic, civil military operations, deception, operations security, and psychological operations. The results of this experiment indicate that refinement to procedures continues to be a viable way to enhance command and staff operations. The development of the structured condition took basic concepts from standard US Army literature on the estimate and proceduralized them into a workbook of instructions, guidelines, checklists, and work sheets. These materials were beneficial to the participants in the structured and computer-supported conditions. Simple job aids and work sheets can be an enormous benefit in helping relatively inexperienced staff consider multiple factors while processing information for tactical decisions.

It is reasonable to expect that even greater gains in performance can be made if variations in procedures are explored and evaluated. In this experiment current procedures were incorporated into manual instructions and job aids and in low-level computer support. The typical means of evaluating or testing new procedures are by staffing proposed written changes for "desk-side" review or trial application and subjective assessment by staffs in the field. This experiment provided an alternative to typical means of evaluation and revealed problems with the estimate that had been suspected before, but for which firm data did not exist. The findings have in turn suggested enhancements.

War gaming and comparison were the most difficult steps in the experimental task. Participants generally lacked the knowledge and experience to make battle projections. They reported that neither doctrine or instruction provides adequate guidance for making war gaming projections. Many of the necessary data bases are lacking, especially in the area of attrition. More comprehensive data bases are available for measures associated with time and distance of movement, but there is often little time for planners to access and assimilate this information manually to allow application to the current situation.

One strategy of planners seems to be to avoid making projections. Comparing the structured and unspecified conditions suggests that when planners war game, even though

the war gaming does not identify differences or if there are highly questionable outcomes, the planners have been helped by trying to make those projections to better visualize and understand the COAs.

Planning might well benefit from automated support to alleviate the analytical and quantitative burden associated with projecting battlefield outcomes. Projection is beyond the role of COAAT with it spreadsheets used for recording and tabulating projections. Participants in the current experiment expressed a need for support to correlation of forces, calculation of combat power ratios, estimation of attrition, and estimation of time and distance parameters. These computational activities can be more accurately and consistently performed by computer than humans, provided that standardized data bases and war gaming algorithms can be generated and accepted by the U.S. Army and the joint services.

Experimental results and participant feedback indicate that procedures and automated support should enhance the user's capability to identify complex interactive factors that can impact upon the success or failure of a mission. While it is important to thoroughly understand the battlefield, it also appears promising to provide user's with procedural job aids and automated support. Projecting battle results and enhancing battlefield visualization are two top candidates for computer support. Computer support tools can be developed that will enhance the user's capability to determine and analyze critical battlefield events that significantly contribute to the likelihood of mission success or failure.

Also it is important to recognize that the computer support used in this experiment has functional characteristics and features that can facilitate tactical decision making. In fact, the task organization and status tool (TOAST) from the Tactical Planning Workstation has been used as a model for a similar tool in a field tactical C^2 system. Also based on the findings from this experiment, the Workstation has been subsequently enhanced with additional tools. Capabilities have been added in the areas of projecting battlefield outcomes and aiding the visualization of the battlefield. This suite of tools called Operations Planning Tools (OPT) has undergone preliminary testing with representative users and has met with high levels of acceptance (Fallesen, 1991a; Fallesen, 1991b; Perkins, Flanagan, & Fallesen, 1991).

Planning tools and decision aids like these offer great potential to commanders and staffs. Only with careful examination of the jobs, knowledge, and styles of soldiers will insightful requirements for effective tactical planning and decision aids emerge. Regardless of whether the potential for enhancement comes from decision aids, improved training, or enriched organizations, the capabilities and limitations of commanders and staffs must be thoroughly understood. As the battlefield grows in complexity and military forces are challenged with new missions and roles, the need for continuing research in all facets of command and control remains strong.

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Appendix A

Background Questionnaire

BACKGROUND INFORMATION

The purpose of this questionnaire is to obtain information relating to the background and experiences of all participants. This information will be used to better understand the findings from the research in which you will participate. All information collected will remain confidential and will not be released to third parties. We appreciate your cooperation in completing this form.

Date: _____

Name: _____ Current Position: _____

Duties of your position: _____

_____

Rank: _____ Branch: _____

Time in Grade: _____ Time in Service: _____

1. What was your area of study in college? _____

   What is your highest level of education? _____

2. Please indicate the year(s) of attendance for the following military schools you have completed.

   _____ Officer Basic Course

   _____ Officer Advanced Course

   _____ Combined Arms & Services Staff School (CAS³)

   _____ Command and General Staff Officer Course (CGSOC) or equivalent. Please list _____

   _____ War College (Non-resident course participant and/or selectee)

3. Please indicate all tactical command or staff positions you have held:

Echelon	Unit Type	Position	Months in Position
_____	___	_____	_____
_____	___	_____	_____
_____	___	_____	_____
_____	___	_____	_____
_____	___	_____	_____
_____	___	_____	_____

4. Indicate your assignments to units that had operational missions in the Fulda Gap area.

Position	Unit	Total Time in Position
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

5. Aside from your assignments, indicate your participation in training exercises that used Fulda Gap terrain.

Position	# CPX's	# FTX's
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

6. Have you ever taken a hands-on computer science course?

   Yes No

7. Indicate your frequency of hands on use during the last six months with the following types of computer equipment.

   Minicomputers and mainframe computers, such as DEC VAX, DEC PDP, large IBM, CDC

   Workstations, such as Sun, Apollo, IBMRT, MASSCOMP

   Personal Computers, such as IBMPC, Apple, Macintosh

Frequency of use	Minicomputers Mainframes	Workstations	Personal Computers
Daily			
Every few days			
Weekly			
Monthly			
Less than monthly			
None			

8. Have you ever used desktop cursor-control devices on workstations and personal computers. Examples are: mouse, track-ball, graph tablet, joy-stick.

Yes No

9. Have you ever written a program for yourself?

Yes No

10. Have you ever written a program for someone else to use?

Yes No

11. Do you own a computer?

Yes No

12. Social Security Number: _____

Your Social Security Number (SSN) is requested in order to access the Officer Longitudinal Research Data Base (OLRDB). The purpose of the OLRDB is to make data available for research on US Army officers from periods of pre- and post-commissioning training and field activities. Historical data from various Army agencies have been incorporated into several data sets. Data are safeguarded in conformance with the Privacy Act of 1974 and are intended for use only in DoD research. Data will not be disclosed in any form about any particular individual to anyone, including the individual, his/her chain of command, Army agencies, or any other third person or organization.

Appendix B

Experimental Task Procedures Workbook

Analyzing Tactical Courses of Action

The analysis and selection of a tactical course of action is described in detail in FM 101-5, Staff Organization and Operations, and Student Text 100-9, The Command Estimate. Each of these manuals discusses in detail the military approach to decision-making and the requisite steps necessary for orderly analysis. The purpose of this workbook is to review this process and provide an easy-to-use guide to assist staff officers in preparing their estimate.

As mentioned in ST 100-9, the estimate process is a complicated and detailed task, and the time stress of modern battlefields will make its application even more difficult; however, the systematic analysis of battlefield events by competent and conscientious officers should produce superior results for complex problems.

Decision-making in the AirLand Battlefield is heavily influenced by both a lack of desired planning time and an influx of possibilities that must be considered. Planning in a vacuum is a luxury that cannot be afforded; rather, it is a continuous, dynamic process that is illustrated in Figure 1 below.

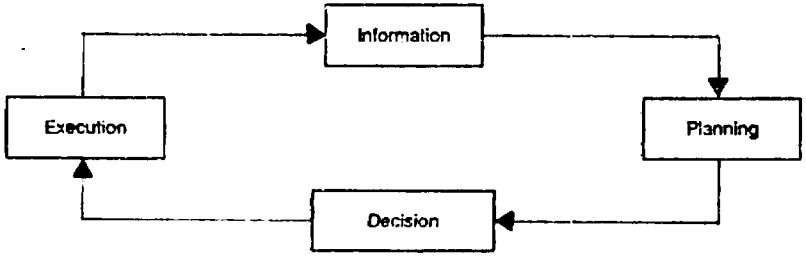

Figure 1. Decision-Making Cycle

All military members involved in the decision-making process must use a logical and fast means of evaluating the battlefield and reaching decisions. To this end, the key to the decision-making process is the estimate of the situation. This process determines the most suitable course of action to accomplish the mission.

Following is an outline of the estimate process that you will use in performing this exercise. This information is provided as a general review of the subject area and as a guide to assist you in evaluation and selection of courses of action. The material has been divided into 9 steps in order to provide a systematic and orderly process that parallels the doctrine in ST 100-9. Figure 2 lists the 9 steps.

COA Analysis Steps

Step	Worksheet	Resource
1 Select courses of action for analysis		Situation Data Base: Div Cmdr's guidance
2 Review area of interest and gather facts (METT-T)	List of Pertinent Facts	Map and overlays Situation Data Base: Friendly forces Enemy forces Analysis of area of operations Reference Data Base
3. List assumptions	List of Assumptions	
4. Array forces for each COA	Map and Tactical Overlays Task Organization Worksheets	Map and overlays Situation Data Base
5. Determine critical events	Map and Tactical Overlays Critical Event Assignment Worksheets	Map and overlays Candidate Critical Event types
Exercise Break		
6. War-game critical events for each COA	Critical Event War-gaming Worksheets	List of Pertinent Facts List of Assumptions Task Organization Worksheets Array of Forces Overlays Lists of Critical Events (graphic and narrative)
7. Aggregate and scale battle results for each COA	War-Gaming Summary Worksheet	Scaling Factors Table (objective measures)
8. Compare courses of action	Course of Action Comparison Worksheet	Subjective Measures Table Scaling Factors Table (subjective measures)
Justify recommended COA	COA Selection and Justification Worksheet	

Step 1

Select Courses of Action for Analysis

DESCRIPTION

The first step in analyzing tactical courses of action is to select the courses of action to be analyzed. These courses of action may be provided by the division commander in his guidance to the staff following mission analysis, or they may be developed by the division G3 and his staff.

In this exercise, the two alternative tactical courses of action are provided in the division commander's planning guidance, and the division chief of staff has directed that you concentrate your analysis on war-gaming of these two courses of action.

PROCEDURE

To view the division commander's guidance, go to the Situation Data Base, consult the table of contents for OPERATIONS, and select the tab for DIV CMDRS GUIDANCE.

Review the guidance carefully as a basis for your analysis of the tactical courses of action.

After you have reviewed the courses of action described in the division commander's guidance, you may proceed to Step 2.

Step 2

Review Area of Interest and Gather Facts (METT-T)

DESCRIPTION

To develop an appreciation of the tactical situation, the staff considers facts it needs to support planning and to properly advise the commander. The information pertains to both friendly and enemy forces as well as to the area of operations (terrain and weather). Key facts are recognized and recorded to support the planning effort.

PROCEDURE

To view the facts available to support your planning, go first to the Situation Data Base and peruse the staff functional areas (personnel, intelligence, operations, and logistics) and selected data categories therein. Carefully select that information which will assist you most in the analysis of the tactical courses of action and in developing the operation estimate. You do not need to view the entire Situation Data Base at this time.

Should you desire to review any pertinent reference data, go to the Reference Data Base and view the staff functional areas and the pertinent data categories therein.

As you review the information, select those facts which are most important and which you need to keep foremost in your mind during your planning effort.

Record these facts in the List of Pertinent Facts. A convenient organization of these facts is METT-T. Additional facts may be added as planning progresses.

After reviewing the available information and listing the pertinent facts on the List of Pertinent Facts worksheet, you may proceed to Step 3.

List of Pertinent Facts

MISSION

ENEMY

TERRAIN AND WEATHER

OWN TROOPS AVAILABLE

TIME

Step 3

List Assumptions

DESCRIPTION

In the step-wise process of analyzing tactical COAs, you would next develop assumptions to replace necessary but missing facts. In this exercise, however, assumptions for planning will be provided to you.

PROCEDURE

The assumptions which you will use for this exercise, as well as the rationale for making those assumptions, are provided to you on the following pages.

Read the assumptions, analyze how they may affect your planning, and keep them in mind as you complete the exercise.

After reviewing the assumptions and the associated rationale, you may proceed to Step 4.

List of Assumptions

Assumptions	Rationale (Why assumption is necessary)

Step 4

Array Forces for Each COA

DESCRIPTION

You will next allocate the available forces which you believe are necessary to successfully execute each COA. You should task organize the division force with adequate combat power allocated to the main attack, supporting attack, and reserve for mission accomplishment. For this exercise, the only forces which we ask you to task organize are those which contribute directly to the combat power of the friendly force; namely, the maneuver battalions, the attack helicopter battalions, and the supporting artillery units.

PROCEDURE

In accomplishing this step you will complete a Task Organization Worksheet (following pages) for each COA. Each of two worksheets is labeled by COA in the upper right-hand corner.

Starting with COA 1, refer to the wall map and tactical overlay available for that COA. From that tactical overlay select the enemy units which oppose each of the main and supporting attacks, and enter them in the corresponding space in the worksheet. Next, select the enemy units which you consider to be reserve or second echelon forces and enter them in the worksheet.

Next, select and task organize the friendly units which you plan to use to conduct the main and supporting attacks and enter them in the worksheet. Similarly, select the friendly units which you plan to place initially in reserve and enter them in the worksheet. Use the situation overlay and force status information (strengths and equipment status) from the Situation Data Base to assist you. Friendly unit stick-ons (blue) are available for your use on the tactical overlay should you desire to use them in task organizing the force.

When you have completed the Task Organization Worksheet for COA 1, repeat the process for COA 2. Task Organization Worksheets for both COA 1 and COA 2 are required.

After you have completed a Task Organization Worksheet for both COAs, you may proceed to Step 5.

Task Organization Worksheet

COA 1

Friendly	Enemy
Main Attack	
Supporting Attack	
Reserve	

Step 5

Determine Critical Events

DESCRIPTION

In accomplishing this step, you will identify and list critical events appropriate for each COA. Critical events are defined as those specified or implied tasks the completion of which are essential to mission accomplishment and which, in the judgment of the analyst, require detailed analysis. In order to develop a critical events list, the analyst must have a mental picture of how the battle will be fought for each COA. There will be times when the list of critical events and decision points may be too long to manage. The analyst must then reduce the list to one that is manageable in the time available for war-gaming. This process requires military judgment to determine which have the highest probability of changing the outcome of the battle and then to restrict the war-gaming to only those critical events.

PROCEDURE

For purposes of identification and assignment of critical events, treat the axis of advance in the north as Axis Alpha and the axis in the south as Axis Bravo.

- Consider COA 1 to consist of a main attack in the north (Axis Alpha) and a supporting attack in the south (Axis Bravo).

- Consider COA 2 to consist of a main attack in the south (Axis Bravo) and a supporting attack in the north (Axis Alpha).

In performing this step, you will use the map and tactical overlay for each COA as well as a CE Assignment Worksheet for each COA. A listing of candidate critical event types appears on the following page.

Post the tactical overlay for the COA which you desire to consider first. Assuming this overlay is for the COA which the division commander identified as COA 1, conduct a map and tactical overlay review and select the first critical event which you expect to occur along Axis Alpha; circle that CE with a grease pencil or marker and label it A1 inside the circle. Next, enter the corresponding CE identification on the CE Assignment Worksheet. For each CE entered in the worksheet, identify the CE by type (see list of CE types or identify your own) and by objective. Enter any desired comments in the worksheet. Following the same procedure, select other CEs, label them on the tactical overlay as A2, A3, ...An, and identify them in the CE Assignment Worksheet. For CEs on the supporting attack axis (Axis B) label the CEs as B11, B12, ...Bn.

For the COA which the division commander identified as COA 2, replace the COA 1 tactical overlay with the overlay for COA 2, and repeat the process of selecting and labeling the CEs on the tactical overlay and of identifying the CEs in the CE Assignment Worksheet. For the main attack axis (Axis B) of COA 2, label the CEs as B1, B2, ...Bn. For CEs on the supporting attack axis, label the CEs as A11, A12, ...A1n.

After you have completed the CE identification on the tactical overlays for both COAs and have completed the CE Assignment Worksheet, you have completed the first phase of the exercise. Additional instructions will be provided to you at this time.

Candidate Critical Event Types

Offensive Missions

Passage of Lines

Penetrate First Defensive Belt

Penetrate Second Defensive Belt

Breach Obstacle Belt

Cross River

Seize Objective

Seize Key Terrain

Seize Town

Deiest Enemy Counter-Attack

Destroy Enemy Force

Capture Enemy Force

Bypass Enemy Force

Seize Beachhead

Fix Enemy in Position

Synchronize with Supporting Forces

Critical Event Assignment Worksheet

(A 1

CE Identification (Axis of Adv, Seq No)	Critical Event Type	Objective	Comment
MAIN ATTACK			
A 1			
A 2			
A 3			
A 4			
A 5			
A 6			
SUPPORTING ATTACK			
B 11			
B 12			
B 13			
B 14			
B 15			
B 16			

Critical Event Assignment Worksheet

DA 2

CE Identification (Axis of Adv, Seq No)	Critical Event Type	Objective	Comment
MAIN ATTACK			
B 1			
B 2			
B 3			
B 4			
B 5			
B 6			
SUPPORTING ATTACK			
A 11			
A 12			
A 13			
A 14			
A 15			
A 16			

Exercise Phase 2

In the second phase of this exercise, you will analyze each COA by war-gaming the critical events of that COA. Results of gaming all critical events of a COA will be aggregated to yield battle results for the parent COA, and these results (or objectives measures) will later be used as one basis for comparing alternative courses of action. To the objective measures for each COA, you will add and consider subjective measures which will influence you in selecting the preferred course of action. Objective and subjective measures will be weighted, scaled, and summed to support your preferred course of action selection. Next, you will recommend a course of action for successful mission accomplishment, and you will justify your recommendation by offering advantages and disadvantages of alternative COAs considered and by presenting a narrative discussion describing the results and key points of your analysis which supports one COA over the other.

The results of the first phase of this exercise differ across the teams participating in the exercise. The second phase of the exercise, therefore, must start from a common baseline of tactical information, facts, assumptions, task organizations, force arrays, and critical events. We have established such a baseline which we desire that you read, understand, and use in your continuing operational planning. Our baseline may differ in a few aspects from the products which you developed during the first phase of the exercise; however, that does not imply that our baseline is any better than the products which you developed. The use of our baseline is essential for control and analysis of our continuing research into tactical decision-making.

The following new baseline documentation is included in your exercise workbook:

List of Pertinent Facts
Division Task Organization Worksheets (COA 1 and 2)
Array of Forces Overlays (COA 1 and 2)
List of Critical Events (COA 1 and 2)

At this point in the exercise, please take the time necessary to read and understand the new planning information presented in the baseline documentation listed above.

When you have read and understand the new information presented, you may move to Step 6.

List of Pertinent Facts

MISSION

- Corps main attack is by 32 AD in the south.
- 16 MID is to seize corps objective ALPHA.
- Division zone has been narrowed to permit better application of combat power.

ENEMY

- Enemy Central Front is a secondary effort; the enemy main effort is in the north.
- Enemy is employing hasty defense.
- 15 MPD is at 60-65%.
- Enemy 1st echelon dispositions within the division sector are stronger in the south.
- Enemy 2d echelon (18 MTR) blocks north avenue.
- 33 GTD is positioned as 2d echelon force of 10 CAA.

TERRAIN AND WEATHER

- Terrain is restricted in north.
- FULDA River is generally unfordable in north but is fordable in the south.
- HAUNE River is fordable.
- Cross country movement of tracked vehicles is generally poor.
- Large scale movement of wheeled and tracked vehicles is considerably restricted in forested and some built-up areas.
- It rained on 1-2 Sep for a total of 1.2 inches; fordability of FULDA and HAUNE Rivers may be affected.
- Lines of communication are good on the north avenue and are fair on the south

TROOPS

- Two (2) bridge companies only are available.
- Division at 85% personnel strength; 82% major equipment items
  - 3 maneuver bns in 3d Bde at low strength
  - 1 maneuver bn in 1st Bde at low strength.
- Ammo: required load = basic load.
- POL: required load = authorized load.
- Corps slice available - FA bde (5 bns), AH Bn (AH-64), Engr (C) Bn, Engr Brg Co, Cml (Smk Gen) Co.
- 26 MID on our north attacks 051200 Sep to seize objectives on IGB.

TIME

- It is now 042000 Sep.
- Attack begins 051200 Sep.

Step 6

War-Game the Courses of Action

DESCRIPTION

War-gaming of tactical courses of action may be divided into successive tasks which will facilitate the gaming process and which may be expected to yield results which will support your selection of a preferred course of action. The war-gaming tasks discussed correspond to those contained in CGSC ST 100-9. You will need to select war-gaming measures to be used to quantify and analyze the results of battle engagements of each critical event. Your final task in this step is to visualize the battle for each critical event. Based upon your visualization of the battle at each critical event, you will make assessments for each of the war-gaming measures you previously selected, and you will record the results for later analysis.

PROCEDURE

You will war-game each COA using a technique of your choice and will assess the battle results. War-gaming of a COA will proceed critical event-by-critical event, and you will record your battle assessments in a CE War-Gaming Worksheet. Your war-gaming of the critical events will be based upon the facts, assumptions, force arrays, and critical events available to you. You should use the avenue-in-depth technique for organizing the battlefield and the critical events for analysis.

For purposes of completing the CE War-Gaming Worksheet, critical event phases are as follows:

Phase A: Actions before the actual critical event. (Usually these actions are those after the consolidation phase of the preceding CE up to the new critical event.)

Phase B: Actions during the critical event.

Phase C: Actions taken upon completion of the critical event (e.g., consolidation, reorganization).

You may war-game at either phase level or CE level. If you war-game at CE level, aggregate your assessments as Phase B.

(Continued)

PROCEDURES (Continued)

To perform the war-gaming activity, you will complete a CE War-Gaming Worksheet for each CE by COA. The CE War-Gaming Worksheet identifies the CE being gamed, divides the CE into three phases discussed above, and offers eight objective war-game measures for the assessment of battle outcome. You need not use all eight measures, but you should use those which provide a good indication of battle outcome for the CE.

Make the war-game assessments using the measures you select for this purpose and enter the results into the appropriate column of the CE War-Gaming Worksheet. If you have divided the critical event into phases, assess each phase seperately. Assessments should be made carefully and consistently as they will be added in a later step. Suggested units of measure are:

Personnel losses	Numbers of persons
Equipment losses	Numbers of major equipment items*
POL expended	Percent of division authorized load
Ammo expended	Percent of division basic load
FEBA movement	Kilometers
Battle duration	Hours and tenths of hours

*See following page for suggested major equipment items.

Repeat the process above until all CEs have been war-gamed and the battle assessments have been made.

When you have made the war-game assessments for all critical events, you may proceed to Step 7.

Critical Event War Gaming Worksheet

COA 1 Critical Event: A 1 CE Type/Objective: Penetrate enemy first echelon

Phase	War-Game Assessment Measures							
	Fr Pers Losses	Fr Equip Losses	En Pers Losses	En Equip Losses	POL Expended	Ammo Expended	FEBA Mvmt	Battle Duration
Phase A - Pre-Critical Event								
Phase B - Critical Event								
Phase C - Consolidation								
CE Total								

Suggested
Major Equipment Items

BLUEFOR	OPFOR
TANK, M1	BMP
Infantry fighting vehicle (IFV) M2	BTR
Cavalry fighting vehicle (CFV) M3	BRDM-GM
Improved TOW vehicle (ITV)	Howitzer, 122mm (Towed or SP)
Howitzer 155mm M109	Howitzer, 152mm (Towed or SP)
Howitzer 203mm M110	Multiple rocket launcher 122mm
Multiple launch rocket system (MLRS)	Tank (T64, T72, T80)
Attack helicopter AH-64	Gun AT, 100mm
	Assault helicopter Mi-8
	Attack helicopter Mi-24

Step 7

Aggregate and Scale Battle Results for Each COA

DESCRIPTION

Once all critical events have been war-gamed, and the battle assessments for each CE have been made, you will aggregate and analyze the results as a means of disclosing from an objective standpoint which of the alternative tactical courses of action is better.

PROCEDURE

In the performance of this step, you will translate the battle assessments for each CE (Step 6) onto War-Gaming Summary Worksheets, one for each COA. You will then total the assessments and scale the totals for goodness.

First, from the CE War-Gaming Worksheets completed in Step 6, bring forward the assessments made and enter them in the *War-Gaming Summary Worksheet* for the appropriate COA. For those war-game assessment measures which you used, total the assessments for each measure for each COA. Remember that the battle duration and FEBA movement are a function of the main attack only.

The next step is to assess the goodness of the assessments which you have made. To do this, consult the Scaling Factors Table (Objective Measures) and enter an appropriate scale number for the total assessments for each measure used. As an example of scaling, and using a scale of 1-to-9 (9 is good), very low friendly personnel casualties would elicit a scaling of 9 for goodness. On the other hand, very high enemy casualties would also be scaled 9 as viewed by the friendly commander. In the absence of weighting across assessment measures, a summation of the goodness for each COA would yield an initial preference for COA selection.

The final action required of you in this step is to review the raw assessment scores and the scaling and to generally compare the two COAs. A more detailed and specific comparison, including consideration of other factors, will occur in Step 8.

For your information in scaling personnel and equipment, the following base numbers apply:

16 Mech Div (reinf) authorized strength	:21,517
16 Mech Div (reinf) authorized major equipment	: 945
15 MRD (reinf) authorized strength	:14,020
15 MRD (reinf) authorized major equipment	: 879

When you have reviewed the battle assessments and scaling in the War-Gaming Summary Worksheet, you may proceed to Step 8.

Scaling Factors Table (Objective Measures)

Factor	Scale	Value
Friendly Personnel Losses (percent)	9	<2
	8	2-4
	7	4-6
	6	6-8
	5	8-10
	4	10-12
	3	12-14
	2	14-16
	1	>16
Friendly Equipment Losses (percent)	9	<10
	8	10-18
	7	18-24
	6	24-29
	5	29-34
	4	34-38
	3	38-41
	2	41-43
	1	>43
Enemy Personnel Losses (percent)	9	>16
	8	14-16
	7	12-14
	6	10-12
	5	8-10
	4	6-8
	3	4-6
	2	2-4
	1	<2
Enemy Equipment Losses (percent)	9	>43
	8	41-43
	7	38-41
	6	34-38
	5	29-34
	4	24-29
	3	18-24
	2	10-18
	1	<10

Factor	Scale	Value
POL Expended (percent auth load)	9	<50
	8	50-90
	7	90-125
	6	125-150
	5	150-170
	4	170-180
	3	180-190
	2	190-200
	1	>200
Ammo Expended (percent basic load)	9	<50
	8	50-90
	7	90-125
	6	125-150
	5	150-170
	4	170-180
	3	180-190
	2	190-200
	1	>200
FEBA Movement (km)	9	>38
	8	36-38
	7	34-36
	6	31-34
	5	28-31
	4	24-28
	3	18-24
	2	10-18
	1	<10
Time (hours and tenths)	9	<24
	8	24-26
	7	26-29
	6	29-32
	5	32-36
	4	36-42
	3	42-50
	2	50-60
	1	>60

Critical Event	War-Game Assessment Measures							
	Fr Pers Losses	Fr Equip Loss	En Pers Losses	En Equip Loss	POL Expended	Ammo Expended	FEBA Mvmt	Battle Duration
Main Attack								
A 1 - Penetrate enemy first echelon								
A 2 - Cross FULDA River								
A 3 - Cross HAUNE River								
A 4 - Seize Objective FOX								
Main Attack Total								
Supporting Attack								
B 11 - Fix enemy in position								
Supporting Attack Total								
COA Total								
Scale (see Table)								

COA 2

War-Gaming Summary Worksheet

Critical Event	War-Game Assessment Measures							
	Fr Pers Losses	Fr Equip Loss	En Pers Losses	En Equip Loss	POL Expended	Ammo Expended	FEBA Mvmt	Battle Duration
Main Attack								
B 1 - Penetrate enemy first echelon								
B 2 - Cross FULDA River								
B 3 - Cross HAUNE River								
B 4 - Defeat counterattack by 18 MTR								
B 5 - Seize Objective WOLF								
Main Attack Total								
Supporting Attack								
A 11 - Fix enemy in position								
Supporting Attack Total								
COA Total								
Scale (see Table)								

Step 8

Compare Courses of Action

DESCRIPTION

To this point in the exercise you have been concerned with those objective measures which may be used to compare COAs. Objective measures are amenable to measurement or quantification. You will now identify subjective measures to be considered in comparing COAs. Subjective measures are not amenable to quantification but must be applied judgmentally. Finally, you will integrate the subjective measures with the objective measures to yield a more expansive basis for comparing COAs and for selecting the preferred COA.

PROCEDURES

In performing this step, you will perform several tasks and will integrate the results using the COA Comparison Worksheet.

The first task which you normally perform is to identify subjective measures which you believe should be considered in selecting a preferred course of action. A Subjective Measures Table is provided on a following page to give you an appreciation of typical subjective measures. In order to provide a baseline for exercise analysis, however, subjective measures have been selected and entered in the COA Comparison Worksheet. You may add other subjective measures to the worksheet if you so desire.

The next task is for you to establish relative weights among the objective and subjective measures, and this is a matter of military experience and judgment. The weight assigned to each measure reflects the relative influence which each measure has upon your evaluation of the merit of the courses of action under consideration. In the COA Comparison Worksheet, assign a weight of 100 to that measure or factor which you judge has the greatest influence upon your selection of a preferred course of action. For example, if conserving friendly equipment for the purpose of conducting future operations is the most important, assign to that objective factor the value of 100. On the other hand, if your judgment reveals that flexibility of the planned COA is the most important factor, then assign that subjective factor the optimum value of 100. All other objective and subjective factors are then weighted in relationship to the one most important factor, and each is assigned a weight less than 100.

(Continued)

PROCEDURES (Continued)

The next task is for you to scale the subjective measures for the degree to which each is incorporated in or supported by each COA under consideration. Scaling tables are provided to guide you in the performance of this task. Remember when you are scaling the subjective factors that the measures will rarely be exhibited with equal goodness in each COA; thus, different scales values will typically be assigned to each COA for any one measure being considered. Enter your selected scale value in the scale column for each COA. In scaling the subjective factor risk, a COA with the lowest risk should be scaled 9 while the one with the highest risk should be scaled 1.

Next, from the War-Gaming Summary Worksheet (Step 7), bring forward the scaled values of the objective measures for each COA and enter them in the scale columns of the COA Comparison Worksheet.

Next, for both objective measures and subjective measures, multiply the assigned weights of each measure by the scale value assigned each measure and enter the result in the appropriate column of the COA Comparison Worksheet. This arithmetic operation must be accomplished for both objective and subjective measures and for the two courses of action. Sum the result columns of the COA Comparison Worksheet for each COA to yield the relative influence of objective and subjective measures on the selection of the preferred COA.

The last task of this step is to analyze the aggregated objective and subjective measures for each COA and to consider their influence on your selection of a recommended COA. The results of your analysis will be used to justify your recommendation of a COA in Step 9.

When you have completed the COA Comparison Worksheet you may proceed to Step 9.

COA Comparison Worksheet

Analysis Category	Weight	COA 1		COA 2	
		Scale	Result	Scale	Result
Objective Measures					
Friendly personnel losses					
Friendly equipment losses					
Enemy personnel losses					
Enemy equipment loss					
POL expended					
Ammo expended					
FEBA movement					
Battle duration					
Objective Measures Total					
Subjective Measures					
Accomplish the mission					
Effective use of assets					
Flexibility					
Facilitate future operations					
Risk					
Subjective Measures Total					

Subjective Measures Table

Principles of War:
- Objective
- Offensive
- Mass
- Economy of Force
- Maneuver
- Unity of Command
- Security
- Surprise
- Simplicity

AirLand Battle Tenets:
- Initiative
- Agility
- Depth
- Synchronization

Other:
- Flexibility
- Mutual Support
- Facilitate Future Operations

Scaling Factors Table
(Subjective measures less risk)

Degree that the measure is supported by, or incorporated in, the COA:

9 High
8
7 Moderately high
6
5 Moderate
4
3 Moderately Low
2
1 Low

Scaling Factors Table
(Risk)

Degree that the measure is incorporated in the COA:

9 Low risk
8
7 Moderately low risk
6
5 Moderate
4
3 Moderately high risk
2
1 High risk

Step 9

Justify Recommended COA

DESCRIPTION

You have now completed the war-gaming of each COA and have analyzed the alternative courses of action both objectively and subjectively. You will now exercise your military judgment and experience to complete the comparison of the COAs and to select a preferred course of action.

PROCEDURES

In this step, complete the COA Selection and Justification Worksheet. Completion of this worksheet will guide you to the major factors which will influence your selection and recommendation of a preferred tactical course of action.

For the alternative courses of action, identify and list the advantages and disadvantages of each course of action using the COA Selection and Justification Worksheet.

After you have listed the advantages and disadvantages of the respective courses of action, analyze and evaluate them and produce a narrative which compares the courses of action from the objective and subjective information available. What you are doing in this task is justifying the selection of one course of action over the other. There cannot be a tie; the commander is looking to you to discriminate between the alternative courses of action based upon the information available and upon your professional judgment. The narrative should be stated in sufficient detail to convince the commander of the recommended COA.

After you have completed your analysis and comparison, enter your recommendation of the preferred tactical course of action at the bottom of the worksheet.

When you have completed the COA Selection and Justification Worksheet, the tactical exercise is completed. Further instructions will be provided to you at this time.

COA Selection and Justification Worksheet

	COA 1	COA 2
Advantages		
Disadvantages		

COA Selection and Just :ation Worksheet (Cont.)

Narrative:

Recommended COA:

Appendix C

Situation Awareness Questionnaire

SITUATION AWARENESS QUESTIONNAIRE

1. Which of the following statements best describes the primary purpose of the mission given to the 16 MID?

   a. destroy enemy in zone
   (b) seize key terrain
   c. fix enemy in position
   d. turn flank of 10 CAA

2. Which of the following is not an implied task for the mission of the 16 MID?

   a. river crossing
   b. coordination with adjacent units
   (c) destruction of bypassed enemy units
   d. passage of lines

3. What is the estimated current strength of the 15 MRD?

   a. 50%
   (b) 60%
   c. 70%
   d. 80%

4. Which of the following 15 MRD regiments is equipped with BMPS?

   a. 45 MRR
   b. 46 MRR
   (c) 47 MRR
   d. all of the above

5. How many maneuver battalions are in the 45 MRR?

   a. 2
   (b) 3
   c. 4
   d. 5

6. Which of the following regiments is strongest in terms of estimated percent of combat strength remaining?

   (a) 18 TR
   b. 45 MRR
   c. 46 MRR
   d. 47 MRR

7. How many artillery battalions are in the RAGs of each of the forward regiments of the 15 MRD?

a. 1
(b) 2
c. 3
d. 4

8. What is the most likely mission of the 33 GTD?

a. 10 CAA second echelon defense forces
(b) mobile reserve
c. hold the right (north) flank of the 10 CAA
d. relieve the 15 MRD

9. Which of the following is <u>not</u> a current weakness of the enemy?

a. resupply
b. maneuver strength
c. helicopter strength
(d) artillery ammunition

10. What is the most likely mission of the 10 CAA?

a. counterattack to disrupt 10 Corps buildup
b. defend in position
(c) delay back to the Fulda river
d. delay back to the IGB

11. What is the mix of mechanized and armored battalions in the 16 MID?

	Mech	Armor
a.	6	4
b.	6	5
(c)	5	5
d.	6	6

12. Which of the following 16 MID battalions is <u>not</u> currently in contact?

a. 2-6 AR
(b) 2-10 AR
c. 2-71 INF
d. 2-74 INF

13. How many ground maneuver battalions are currently in the reserve brigade (2 BDE)?

a. 1
(b) 2
c. 3
d. 4

14. How many AH battalions are currently under division control (not counting the Armored Cav Squadron)?

a. two AH-1 bns
b. two AH-1 bns and one AH-64 bn
c. two AN-64 bns and one AH-1 bn
(d) three AH-64 bns

15. What is the total number of 155mm howitzer battalions currently assigned or attached to the division?

a. 3
b. 4
c. 5
(d) 6

16. Which of the following was not an assumption/conclusion contained in the division personnel estimate?

a. COA 2 can best be supported from a personnel standpoint.
(b) Projected replaced rates will match casualty rates over the mission time period.
c. Significant combat arms replacements will be required upon mission completion.
d. Expected daily casualty rate will not exceed 3 percent.

17. Which of the following was not an assumption/conclusion contained in the division logistics estimate?

(a) COA 2 can best be supported from a logistics standpoint.
b. Supplies will be available to support continued offensive operations as planned.
c. Shortage of cargo transportation in maneuver battalions may impact combat operations if resupply is not forthcoming.
d. Hard-surface MSRs are available to support either COA.

18. How many CAS sorties has the 16 MID been allocated for this mission?

(a) 32
b. 42
c. 48
d. 56

19. Where is the Fulda River most fordable in the division AO?

(a) south
b. central
c. north
d. equally fordable throughout

20. What is the approximate distance in kilometers from the current FLOT to the objective?

a. 30
b. 40
c. 50
d. 60

21. Which of the following urban areas is <u>not</u> in the division AO?

a. Lauterbach
b. Schlitz
c. Hunfeld
d. Fulda

22. Approximately how many kilometers is it from the current FLOT to the Fulda River along avenue ALPHA (northern avenue)?

a. 10
b. 15
c. 20
d. 25

23. On what day relative to the mission is the next rain expected?

a. first day
b. second day
c. third day
d. fourth day

24. Wind direction for the next two days will be generally out of the:

a. north
b. south
c. east
d. west

25. Which type of terrain is most prevalent in the division AO west of the Fulda River?

a. Go
b. Slow-Go
c. No-Go
d. about equal

26. How many times will the division have to cross an Autobahn between the current FLOT and the objective?

a. none
b. once
c. twice
d. three times

27. Within how many hours of H-Hour (051200 Sep) must the division be on the objective?

a. 18
b. 24
c. 36
(d.) not in the corps order

28. Relative to the 16 MID attack, when is the 32 MID attack to begin?

a. 4 hours earlier
(b.) simultaneously
c. 4 hours later
d. 6 hours later

29. Which of the following is the division commander's preference for force distribution in the attack?

(a.) two brigades on line with a strong reserve
b. two brigades on line with a small reserve
c. all three brigades on line
d. no preference given

30. Which of the following was not a special concern of the division commander according to his guidance?

a. indications of possible enemy use of nuclear weapons
b. indications of reinforcement of enemy units in contact
(c.) indications of counterattack by 15 MRD
d. indications of movement of the 14 TA

31. The 32 AD will relieve elements of the 16 MID on the right (south) flank:

a. during the night of 04/05 Sep
b. by dawn, 05 Sep
c. prior to 051200 Sep
(d.) following the passage of lines at 051200 Sep

32. Which of the following best describes the mission of the 313 Sep Mech Bde?

a. act as corps RACO force throughout the mission
(b.) follow 16 MID, be prepared for commitment in zones of 16 MID and 32 AD in order
c. follow 32 AD, be prepared for commitment in zones of 32 AD and 16 MID in order
d. attached to 12 MID as corps reserve

Appendix D

COA Analysis Task Evaluation

Name: _____

COA ANALYSIS TASK EVALUATION

Below are a series of questions concerning your evaluation of the procedure you followed in performing COA analysis.

1. Please rank order the six (6) most important data categories in the Situation data base for use in performing the COA analysis.

SITUATION DATA

Personnel

_____ Strengths
_____ Losses and Gains
_____ Other Personnel
_____ Pers Estimate

Intelligence

_____ OPFOR Composition
_____ OPFOR Committed
_____ OPFOR Reinforcements
_____ OPFOR Artillery
_____ Intelligence Estimate
_____ Intell Reports
_____ Weather History
_____ Weather Forecast

Operations

_____ Current Operations
_____ Tactical Overlay
_____ Task Organization
_____ Corps Frag Order
_____ Division Cmdr's Guidance

Logistics

_____ Class III Supply
_____ Class V Supply
_____ Equipment Status
_____ Logistics Estimate

2. Please rank order the four (4) most important data categories in the Reference data base for use in performing the COA analysis.

REFERENCE DATA

Personnel

_____ Strengths
_____ Battle Losses
_____ Prisoners of War

Intelligence

_____ Composition
_____ Strengths
_____ Equipment
_____ Equipment Characteristics

Operations

_____ Organization
_____ Equipment
_____ Equipment Characteristics
_____ Minefields

Logistics

_____ Supply
_____ Transp - Payloads

3. Please indicate the amount of effort you expended performing each of the following potential activities as part of the COA analysis task. Circle the phrase that most closely indicates the amount of effort.

	1	2	3	4	5
Review area of interest and gather facts (METT-T)	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort
Array forces for each COA	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort
Determine critical events (segment the battlefield for analysis)	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort
War-game critical events (visualize the battle, determine battle results)	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort
Aggregate and compile battle results for each COA	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort
Compare Courses of Action	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort
List advantages and disadvantages of each COA, and select recommended COA	Very High Effort	Considerable Effort	Some Effort	Little Effort	No Effort

4. How difficult was it to perform each of the following potential activities as part of the COA analysis task? Please circle the phrase that most closely indicates the degree of difficulty. Don't answer for an activity for which no effort was expended (Question 3 above).

	1	2	3	4	5
Review area of interest and gather facts (METT-T)	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Array forces for each COA	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Determine critical events (segment the battlefield for analysis)	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
War-game critical events (visualize the battle, determine battle results)	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Aggregate and compile battle results for each COA	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Compare Courses of Action	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
List advantages and disadvantages of each COA, and select recommended COA	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult

Name: _____

COA ANALYSIS TASK EVALUATION

Below are a series of questions concerning your evaluation of the procedure you followed in performing COA analysis.

1. Please rank order the six (6) most important data categories in the Situation data base for use in performing the COA analysis.

SITUATION DATA

Personnel

_____ Strengths
_____ Losses and Gains
_____ Other Personnel
_____ Pers Estimate

Operations

_____ Current Operations
_____ Tactical Overlay
_____ Task Organization
_____ Corps Frag Order
_____ Division Cmdr's Guidance

Intelligence

_____ OPFOR Composition
_____ OPFOR Committed
_____ OPFOR Reinforcements
_____ OPFOR Artillery
_____ Intelligence Estimate
_____ Intell Reports
_____ Weather History
_____ Weather Forecast

Logistics

_____ Class III Supply
_____ Class V Supply
_____ Equipment Status
_____ Logistics Estimate

2. Please rank order the four (4) most important data categories in the Reference data base for use in performing the COA analysis.

REFERENCE DATA

Personnel

_____ Strengths
_____ Battle Losses
_____ Prisoners of War

Operations

_____ Organization
_____ Equipment
_____ Equipment Characteristics
_____ Minefields

Intelligence

_____ Composition
_____ Strengths
_____ Equipment
_____ Equipment Characteristics

Logistics

_____ Supply
_____ Transp - Payloads

3. How difficult was it to perform each of the steps of COA analysis listed below? Please circle the phrase that most closely indicates the degree of difficulty.

	1	2	3	4	5
Step 2. Review area of interest and gather facts (METT-T)	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Step 4. Array forces for each COA	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Step 5. Determine critical events	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Step 6. War-game critical events	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Step 7. Aggregate and scale battle results for each war-game measure	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Step 8. Compare Courses of Action	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult
Step 9. List advantages and disadvantages of each COA, and select recommended COA	Very Difficult	Considerable Difficulty	Some Difficulty	Little Difficulty	Not Difficult

4. Did you start forming a conclusion about the preferred Course of Action prior to step 8, Comparison of COAs?

YES NO

If YES:

a. Did your conclusion agree with your eventual recommended COA?

YES NO

b. During what step did you reach your conclusion?

____ Step 2, Gather Facts
____ Step 4, Array the Forces
____ Step 5, Identify CEs
____ Step 6, War-game CEs
____ Step 7, Aggregate Results

5. My understanding of the reason for scaling the war-gaming and subjective measures is (please circle the letter of the most appropriate statement):

A. Each measure is put on a common basis of measurement and comparison, so the measures could be added together.

B. Prevents the possibility of zeroing out certain measures during later compilation of results.

C. Increases the amount of discrimination among the Courses of Action.

D. Serves as a ballpark check on the quantitative estimates that were made.

6. How confident are you that your estimates for the war-gaming measures were accurate enough to support COA selection? Please circle the phrase that most closely indicates your degree of confidence.

	1	2	3	4	5
Friendly personnel casualties	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
Friendly equipment casualties	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
Enemy personnel casualties	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
Enemy equipment casualties	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
POL expended	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
Ammunition expended	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
FEBA movement	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident
Battle duration	Not Confident At All	Not Very Confident	Somewhat Confident	Fairly Confident	Extremely Confident

7. Did you generally agree with the value ranges assigned to each scale value for the measures (refer to the list of scale ranges provided below)?

YES NO

If NO, what would you change (make appropriate changes on the list)?

Factor	Scale	Value
Friendly Personnel Losses (percent)	9	<2
	8	2-4
	7	4-6
	6	6-8
	5	8-10
	4	10-12
	3	12-14
	2	14-16
	1	>16
Friendly Equipment Losses (percent)	9	<10
	8	10-18
	7	18-24
	6	24-29
	5	29-34
	4	34-38
	3	38-41
	2	41-43
	1	>43
Enemy Personnel Losses (percent)	9	>16
	8	14-16
	7	12-14
	6	10-12
	5	8-10
	4	6-8
	3	4-6
	2	2-4
	1	<2
Enemy Equipment Losses (percent)	9	>43
	8	41-43
	7	38-41
	6	34-38
	5	29-34
	4	24-29
	3	18-24
	2	10-18
	1	<10

Factor	Scale	Value
POL Expended (percent of authorized load)	9	<50
	8	50-90
	7	90-125
	6	125-150
	5	150-170
	4	170-180
	3	180-190
	2	190-200
	1	>200
Ammo Expended (percent basic load)	9	<50
	8	50-90
	7	90-125
	6	125-150
	5	150-170
	4	170-180
	3	180-190
	2	190-200
	1	>200
FEBA Movement (km)	9	>38
	8	36-38
	7	34-36
	6	31-34
	5	28-31
	4	24-28
	3	18-24
	2	10-18
	1	<10
Time (hours and tenths)	9	<24
	8	24-26
	7	26-29
	6	29-32
	5	32-36
	4	36-42
	3	42-50
	2	50-60
	1	>60

Appendix E

Human-Machine Interface Evaluation

Name: _____

HUMAN-MACHINE INTERFACE EVALUATION

Below are a series of questions concerning your impressions of using the Sun workstation for COA analysis.

1. How well are the Situation Data and Reference Data Menus labeled and organized for easy and logical access to data (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Hard to use		OK		Easy to use

2. For the purpose of conducting a COA analysis, are the map background, map scale, map features, and tactical overlay laid out in an operationally logical manner so you can find the information you want quickly (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Hard to use		OK		Easy to use

Please specify the areas you feel need improvement. If possible, please suggest improvements.

3. In each of the map display categories below, please rank order the individual attributes from one (1) for the most useful attribute, to four (4) for the least useful attribute (1 - 6 for the Map Features category).

MAP FEATURES

_____ Grids
_____ Contours
_____ Roads
_____ Hydrography
_____ Built-up Areas
_____ Misc. Features

MAP BACKGROUND

_____ Shaded Relief
_____ Vegetation
_____ Elevation Banding
_____ None

MAP SCALES

_____ 1 : 80,000
_____ 1 : 160,000
_____ 1 : 400,000
_____ 1 : 800,000

TACTICAL OVERLAY

_____ Show BLUEFOR Units
_____ Show BLUEFOR Control Measures
_____ Show OPFOR Units
_____ Show OPFOR Control Measures

4. Are the labels for the map display categories in question 3 above consistent with terminology used by Army personnel?

YES NO

If NO, please circle some of the worst offending labels in the list in question 3.

5. While identifying Critical Events, was it easy to enter CEs in the tactical overlay using the Sun workstation?

YES NO

If NO, explain the problem.

6. How easy was it to coordinate the use of both the Sun and Symbolics workstations while identifying Critical Events (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Difficult	Somewhat Difficult	Somewhat Easy	Easy	Very Easy

If rated (1) or (2), explain the problem.

7. How easy was it to use the "walking" menus to request displays and perform actions (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Hard to use		OK		Easy to use

8. How easy was it to use the Task Organization tool to review and modify the task organization, and obtain updated unit status (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Hard to use		OK		Easy to use

Name: _____

HUMAN-MACHINE INTERFACE EVALUATION (WITH COAAT)

Below are a series of questions concerning your impressions of using both the Sun and Symbolics workstation for COA analysis.

1. How well are the Situation Data and Reference Data Menus labeled and organized for easy and logical access to data (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Hard to use		OK		Easy to use

2. For the purpose of conducting a COA analysis, are the map background, map scale, map features, and tactical overlay laid out in an operationally logical manner so you can find the information you want quickly (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Hard to use		OK		Easy to use

Please specify the areas you feel need improvement. If possible, please suggest improvements.

E-3

3. In each of the map display categories below, please rank order the individual attributes from one (1) for the most useful attribute, to four (4) for the least useful attribute (1 - 6 for the Map Features category).

MAP FEATURES

_____ Grids
_____ Contours
_____ Roads
_____ Hydrography
_____ Built-up Areas
_____ Misc. Features

MAP BACKGROUND

_____ Shaded Relief
_____ Vegetation
_____ Elevation Banding
_____ None

MAP SCALES

_____ 1 : 80,000
_____ 1 : 160,000
_____ 1 : 400,000
_____ 1 : 800,000

TACTICAL OVERLAY

_____ Show BLUEFOR Units
_____ Show BLUEFOR Control Measures
_____ Show OPFOR Units
_____ Show OPFOR Control Measures

4. Are the labels for the map display categories in question 3 above consistent with terminology used by Army personnel?

YES NO

If NO, please circle some of the worst offending labels in the list in question 3.

5. How easy was it to coordinate the use of both the Sun and Symbolics workstations while identifying Critical Events (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Difficult	Somewhat Difficult	Somewhat Easy	Easy	Very Easy

If rated (1) or (2), explain the problem.

6. How easy was it to assign Critical Events to COAs on the Symbolics workstations? (please circle the appropriate number on the rating scale below)?

1	2	3	4	5
Difficult	Somewhat Difficult	Somewhat Easy	Easy	Very Easy

7. How easy was it to insert and aggregate war-gaming results for the various measures (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Difficult	Somewhat Difficult	Somewhat Easy	Easy	Very Easy

8. How useful were the instructions that preceeded each worksheet on the Symbolics screen, and the prompts that guided actions while completing each worksheet (please circle the appropriate number in the rating scale below)?

1	2	3	4	5
Of no use	Not very useful	Of use	Of considerable use	Extremely useful

Appendix F

Team Profile Work Sheet

Exp. Code _____ Date _____

TEAM PROFILE

Observer _____

WORK MANAGEMENT

Criteria	Observation
Did the team make a conscious effort to organize work (verbal discussion)? What did they discuss and agree to? How much time did they spend?	
Did they follow their work allocation? Did they refer back to the plan? Did they improve the plan?	
Did they manage the progression of work (time and sequence)? Did they get distracted? Were they able to get back on track?	
Work Management transitions and progressions: In-context appraisals In-context questions Out-of-context appraisals Out-of-context questions New information Old information Natural resolution Return to previous context Time break/change of circumstances Forced change Option generation	

Exp. Code _____ Date _____

TEAM PROFILE

Observer _____

TEAM DYNAMICS

Criteria	Observation
Did the team members have equal status on team? Was a leader/subordinate relationship arranged? Did the subordinate accept his role? Was the leader adequate? Was there any conflict of roles?	
Was one team member "dominant" in terms of experience, knowledge, or motivation? Which one?	
Were there any "extreme" behaviors or opinions expressed?	
Other team interaction observations.	

Exp. Code _____ Date _____

TEAM PROFILE

Observer _____

PERFORMANCE STYLE AND STRATEGY

Criteria	Observation
Did one team member discount or redo the partner's work?	
How was consensus achieved? How were conflicts resolved? How was cooperation on problems effected?	
What was the problem solving process? - Goal-oriented - Degree of structure - Consistency - Quantitative - Qualitative - Analytic - Opinion	
Was the advocacy approach "healthy" (challenges assertions and results) or "unhealthy" (opposition or "groupthink")?	
What was their method of capturing results, keeping an audit trail, recording their thinking and analysis?	
Did they perform each phase of work just adequately, or "good enough"? Did they attempt to maximize effort on each phase of work by validating and checking data and their results?	

Exp. Code _____ Date _____

TEAM PROFILE

Observer _____

PERFORMANCE RESULTS

Criteria	Observation
How early did a COA appear to be selected? Was marshalling or filtering of data done to support the "pre-selected" COA? Did judgments change on the preferred COA? Were the COAs modified or refined during wargaming (relative number of refinements proposed or rejected for each COA)?	
Was error checking performed? How often? How was it done? What were the results?	
Other performance observations	

Exp. Code _____ Date _____

TEAM PROFILE

Observer _____

USE OF MEDIA

Criteria	Observation
What was the relative use of media for information acquisition and record keeping (amount of time, number of times)? - Paper maps	
- Reference materials	
- Scenario notebook	
- Sun workstation	
- COAAT workstation	
- Workbooks	
- Other notes	